

# **NASA Technical Memorandum 104566, Volume 8**

## **SeaWiFS Technical Report Series**

**Stanford B. Hooker, Editor**  
*NASA Goddard Space Flight Center*  
*Greenbelt, Maryland*

**Elaine R. Firestone, Technical Editor**  
*General Sciences Corporation*  
*Laurel, Maryland*

## **Volume 8, Proceedings of the First SeaWiFS Science Team Meeting**

**Stanford B. Hooker and Wayne E. Esaias**  
*NASA Goddard Space Flight Center*  
*Greenbelt, Maryland*

**Lisa A. Rexrode**  
*General Sciences Corporation*  
*Laurel, Maryland*



National Aeronautics and  
Space Administration

**Goddard Space Flight Center**  
Greenbelt, Maryland 20771

PREFACE

The occasion of the First SeaWiFS Science Team Meeting represents a major milestone on behalf of the ocean color community to renew satellite ocean color observations following the Coastal Zone Color Scanner (CZCS) proof-of-concept mission. The meeting was hosted by the SeaWiFS Project and attended by 56 team members (or their delegates) representing 17 countries, plus observers from many U.S. and foreign agencies, institutions, and corporations. The breadth of interest and expertise attests to the maturity of this new field, and to the importance attached to the SeaWiFS mission.

These Proceedings of the meeting attempt to summarize the major deliberations of the group, and to provide a current directory of investigations. It is somewhat unusual in NASA programs to institute a science team of this size relatively late with respect to the expected launch date, but the complexion of the mission is quite different from what has been attempted in the past. Therefore, one of the objectives of the meeting was to brief team members and agency representatives on the status of the program, and to elicit comments and recommendations for needed changes, additions, or deletions to the program.

The group was very successful in accomplishing the primary goals, from the Project's perspective. For the most part, the Project came away with a strong endorsement of its approach and performance in most areas. This is attributed primarily to the excellent scientific advice the Project received from the SeaWiFS Prelaunch Science Working Group, and the serious consideration of the advice by the Project. Additionally, with the help of session chairs during working groups, the Science Team provided clearly stated recommendations at the meeting in areas where advice was sought by the Project or where alterations would be beneficial to the mission.

The launch of the SeaStar spacecraft carrying the SeaWiFS sensor is approximately six months distant at this writing. Consequently, the authors have made every attempt to compile these proceedings as rapidly as possible and to include all Science Team recommendations. Action on some of the recommendations has already been taken by the Project or organizations with Project responsibilities, like the Goddard Distributed Active Archive Center (DAAC), while others will require further study. It is unlikely that all of the recommended changes can be implemented for launch, due to cost and schedule constraints, but all will be considered carefully. Progress on these latter items will be tracked by the Project, and the Team will be kept informed of important developments via electronic mail and other means. Time does not permit a thorough review by every participant, so the authors take responsibility for all errors and inaccuracies present. We urge readers to bring any errors to our attention.

There was a great sense of optimism and excitement at the meeting because resumption of routine observations of ocean color, with significant improvements in data quality and quantity, is now close at hand. The joint commercial and research approach has enabled a faster and more affordable mission, and has required adaptations in how the research community interfaces with the mission and data archives. Continued active participation of Science Team members and the research community will help assure that this experimental approach and scientific mission fulfills not only the fiscal and schedule goals, but most importantly, the scientific goals as well. We look forward to an active series of working group meetings and the next full Science Team meeting for progress along these lines, and within the next year, to the initial results of the science investigations using SeaWiFS data.

Many individuals contributed to the success of the meeting in terms of preparation of documentation, logistical arrangements, and strong positive attitudes. I would like to express my appreciation to Project personnel, DAAC V0 personnel, and especially to Dr. Stan Hooker, Ms. Connie Hall, and Ms. Meta Frost for their excellent support in conducting the meeting.

*Greenbelt, Maryland  
February 1993*

— W. E. Esaias

## ABSTRACT

The first meeting of the SeaWiFS Science Team was held January 19–22, 1993 in Annapolis, Maryland, in preparation for a launch of the SeaStar satellite carrying the SeaWiFS ocean color sensor in the October 1993 time frame. The primary goals of the meeting were: 1) to brief Science Team members, agency representatives, and international collaborators in considerable detail on the status of the mission by representatives from the SeaWiFS Project, the prime contractor Orbital Sciences Corporation (OSC), and the Goddard Distributed Active Archive Center (DAAC); 2) to provide for briefings on the science investigations undertaken by Science Team members and to solicit comments and recommendations from meeting attendees for improvements; and 3) to improve coordination of research and validation activities both inter- and intra-nationally with respect to collection, validation, and application of ocean color data from the SeaWiFS mission. Following the presentations, working groups met more informally for in-depth discussions covering all aspects of the mission and underlying scientific questions. These deliberations resulted in 60 specific recommendations concerning the mission, each of which was reviewed in plenary session to develop a consensus position. The SeaWiFS Project and the Goddard DAAC have developed a list of action items based on the recommendations and will provide their response to each of the recommendations in a timely fashion.

## 1. INTRODUCTION

SeaWiFS, the Sea-viewing Wide Field-of-view Sensor, will bring to the ocean community a welcomed and improved renewal of the ocean color remote sensing capability lost when the Nimbus-7 Coastal Zone Color Scanner (CZCS) ceased operating in 1986. SeaWiFS is part of the Earth Probes initiative within the National Aeronautics and Space Administration (NASA) which emphasizes satellites with short lead times and simple launch requirements. The purpose of SeaWiFS is to examine factors that affect global change. Because of the role of phytoplankton in the global carbon cycle, data obtained from SeaWiFS will be used to assess the ocean's role in the global carbon cycle as well as other biogeochemical cycles. SeaWiFS data will be used to help elucidate the magnitude and variability of the annual cycle of primary production by marine phytoplankton and to determine the distribution and timing of spring blooms. The observations will help to visualize the dynamics of ocean and coastal currents and eddies, the physics of mixing, and the relationships between ocean physics and large-scale patterns of productivity. The data will help fill the gap in ocean biological observations between those of the CZCS and the Moderate Resolution Imaging Spectrometer (MODIS), which is part of the Earth Observing Satellite (EOS) program.

The SeaWiFS Project (Code 970.2) hosted its first SeaWiFS Science Team (SST) meeting in Annapolis, Maryland from January 19–22 at the Historic Inns of Annapolis. The meeting was organized with the following objectives in mind: 1) to familiarize each Science Team member with the goals and proposed science of other team members; 2) to brief the Science Team on the current status of the Project and provide an opportunity for the Science Team to make recommendations on issues facing the Proj-

ect; and 3) to assemble representatives of the wider ocean color community so a more integrated approach to bio-optics can be established.

Mission overviews from NASA Headquarters (HQ), the Goddard Space Flight Center (GSFC), the Project, and OSC, the principal contractor, were given, along with perspectives from other government agencies addressing the relevance of SeaWiFS to ongoing or planned projects. The latter were followed by detailed baselines of the primary elements of the Project and summaries of work done by investigators under contract with the Project. The baselines established what actions are being pursued for the fundamental issues facing the Project and will be the primary criteria for determining whether or not the Project is meeting its objectives and the concerns of the wider community.

Summaries of what each team member proposed to do were given before the meeting divided into working groups to address issues requiring more discussion or a consensus of opinion. On the last day, issues and recommendations from the various working group leaders were presented for discussion and approval. After the plenary session adjourned, the participants attended either a tour of OSC or a tour of the Project. The former allowed participants to see space hardware and OSC's facilities, while the latter was devoted to Project demonstrations and tours of GSFC's facilities.

### 1.1 Invited Presentations

Following introductions by the Project Scientist, Wayne Esaias, Dixon Butler and Frank Muller-Karger discussed issues at NASA HQ which are affecting or will affect SeaWiFS. The Research and Applications (R&A) budget has absorbed a \$21 million cut for Landsat and the Upper At-

mosphere Research Satellite (UARS). Within the budget environment, SeaWiFS needs to *maximize the quality of the product*, establish a data archive, and lay the *conceptual groundwork* for the next decade of ocean remote-sensing science. Frank Muller-Karger noted political action might be needed to strengthen the prospects for SeaWiFS and beyond. Vince Salomonson completed the upper management overview. He hailed SeaWiFS as being innovative and presented the connections to MODIS and the Goddard DAAC.

Bob Kirk presented the SeaWiFS Project organization and explained the roles and responsibilities of each project member. His project status overview covered five areas:

1. The sensor is completed and undergoing testing.
2. The spacecraft engineering development units have been tested and many flight units have been started, but they are behind schedule.
3. The launch involves three firsts: 1) use of a *Stretch Pegasus*, which has a tight motor delivery schedule; 2) use of a new L-1011 carrier aircraft; and 3) use of the Vandenberg assembly facility.
4. The OSC ground control system design is complete, construction has begun, and the decryption box is in development.
5. The GSFC system is on schedule and will undergo an end-to-end test in March.

He also noted in his remarks that all SeaWiFS data will be put in the public domain five years after collection.

Wayne Esaias gave an overview of the various groups involved with SeaWiFS and presented the Project's data policy (see Appendix A). OSC will build, launch, and operate SeaStar (the spacecraft carrying the SeaWiFS sensor), and will then sell the data to NASA and commercial users. Although the contract with OSC is for a *data buy*, NASA specified the data quality and characteristics, and will provide the following throughout the five-year lifetime of the mission: a) data for research users, b) development of research algorithms, c) calibration and validation functions, and d) processing and archiving of global data. A comparison of the CZCS and SeaWiFS sensors was also given, and improvements of the latter with respect to the former were clearly identified.

Antonio Elias from OSC described the contract OSC has with NASA and emphasized the following: a) the contract represents a fixed-price *data sale*—there is no chance for a cost increase; b) SeaStar is the first privately owned remote sensing satellite in history; c) NASA and OSC are an effective team—this is the smoothest running contract OSC has seen with much less paperwork than usual; and d) both sides profit from this architecture since costs to NASA are lower and OSC has an opportunity for higher profits from commercial ventures. He ended by saying OSC wants this kind of contract in the future.

Keith Lyon, also from OSC, presented the current status of SeaStar and OSC with regard to SeaWiFS. He highlighted several important points: a) due to the delay of the spacecraft preceding SeaStar, there has been schedule erosion—the key is personnel conflicts within OSC for each mission; b) the launch time frame is August–October, 1993 (R. Kirk later mentioned October 15 is likely); c) the decoder interface is ready; d) the ground station will be in Fairmont, West Virginia, with operational control in Sterling, Virginia; and e) a newsletter will come out shortly and there is a customer service line.

Richard Roberts and Alan Holmes, from Hughes/Santa Barbara Research Center (SBRC), described the status of the SeaWiFS sensor. Environmental testing will take place in January. Richard Roberts showed the various electronic boards and redundancies, leading to a discussion of which boards could be removed to save weight. Science Team members said removal of useful redundant boards should only be considered as a last alternative. Alan Holmes presented summaries for when the sensor was used to collect data from the moon, sun, and blue sky. The sensor appeared to be functioning as expected.

Bob Winokur, from the Office of the Oceanographer of the Navy, indicated Navy Operations would focus on the coastal environment for support of expeditionary forces. He emphasized the application of ocean color to naval warfare within which the diffuse attenuation length and coastal circulation patterns are a high priority. Optical clarity data might be utilized for non-acoustic detection of submersibles. The primary application of SeaWiFS data to Navy needs would be to contribute to defining the environment in question for operations, system design, sensor performance predictions, and naval planning activities. SeaWiFS data will also contribute to the development and updating of a global optical climatology database.

Mike Reeve, representing the National Science Foundation (NSF), stressed NSF has been on an ocean color roller coaster. The budget, including ship support, is down 3–4%. NSF is the lead agency for the Joint Global Ocean Flux Study (JGOFS), with a budget of \$12 million—which should have been \$20 million—it has a ship operations budget shortfall of \$3 million. Mike Reeve saw maneuvering room in the 1994–1995 time frame, and mentioned the bio-optics cruise planned as part of the JGOFS Arabian Sea Process Study. He also discussed interactions with the World Ocean Circulation Experiment (WOCE) community, which has designated berths on ships for CO<sub>2</sub> and bio-optics. Other issues discussed were the *in situ* data policy and *cross-fertilization* of investigators within SeaWiFS and EOS, to develop an optimum coordination strategy. Greg Mitchell responded to ship-time concerns, and suggested a *Multi-Agency Ship-Scheduling for SeaWiFS* (MASSS) conference, involving NSF, the Navy, and the National Oceanic and Atmospheric Administration (NOAA).

Kathy Sullivan of NOAA represented the interests of several different NOAA programs, including the National

Environmental Satellite Data Information Service (NESDIS), the National Ocean Service (NOS), and the National Marine Fisheries Service (NMFS). There is strong interest in (high resolution) local area coverage (LAC) data for coastal areas [as opposed to the coarse resolution global area coverage (GAC) data]. Recruitment and distribution of fish is important to fisheries, and there are water quality issues in the estuarine-ocean transitional zone. NOAA is prepared to help support the deployment and maintenance of the Marine Optical Buoy (MOBY), although five ship days on a quarterly basis is *tough*. NOAA is committed to LAC archive and data capture, as well as a yearly validation cruise.

Rick Spinrad spoke for the Office of Naval Research (ONR). He emphasized the partnership with the Naval Research Laboratory (NRL), and highlighted ONR interests. Coastal and shallow water (littoral zone) has strong emphasis, as it is the area which must be controlled to support on-shore military operations. Some of the waters involved are Case 1, but most are Case 2. Environmental quality, pollutant fate, sediment-water exchange and air-sea exchange are also important along coasts, and within harbors and estuaries. ONR does not have an ocean color group, but has an Ocean Optics group and an Oceanic Biology group. He noted ONR is an active Arabian Sea player, with the accelerated research initiative (ARI) effort now managed by Charlie Yentsch. There is a Coastal Ocean Optics Program (COOP) effort planned for 1995, and interest in an iron fertilization experiment.

George Saunders of the Department of Energy (DOE) described DOE efforts within the Environmental Sciences Division, primarily oceanic CO<sub>2</sub> measurements in cooperation with WOCE and JGOFS. The Ocean Margins program will concentrate on factors affecting carbon in the Cape Hatteras region. This includes atmospheric interaction, production, remineralization, transport, and burial processes. Photosynthetic fixation in Case 2 waters will be emphasized. Data from SeaWiFS will aid estimation of irradiance, optical properties, pigments, and coastal circulation patterns. SeaWiFS measurements can be ground-truthed and will provide estimates of process intensity over several scales of variability.

## 1.2 Project and MODIS Presentations

Watson Gregg presented Mission Operations baselines. He emphasized the three major goals of the mission: five-year lifetime, global coverage, and maximum scientific usefulness. Examples of coverage were presented under various power constraints. The at-launch power budget allows for a 40 min. duty cycle per orbit. Examples of coverage that emphasized the effects of clouds, sun glint contamination, and several tilt strategies were also shown. The navigation strategy was described.

Chuck Vermillion described the GSFC Data Capture Facility and presented the data acquisition baselines. The

primary technical function of the Data Capture Facility is to provide technical consultation and support in the following four areas:

- 1) Phone and written technical support regarding the front-end, ingest, and image processing components of the NASA supported ground stations,
- 2) Level-0 frame synchronized output format for NASA supported ground stations,
- 3) SeaWiFS High Resolution Picture Transmission (HRPT) level-1a modular software for NASA supported ground stations, and
- 4) On-site system integration support on a case-by-case basis.

Gene Feldman presented the SeaWiFS Data Processing baselines, emphasizing the following points: 1) large volumes of SeaWiFS data must be processed in a timely fashion; 2) processing control should require as little human intervention as possible; 3) changes in the processing scheme, e.g., new algorithms, should be easily incorporated or removed; 4) multiple processing *threads* must be able to run concurrently; and 5) the processing methodologies and data products must be fully documented. The system has been in a *run and break* mode to refine the proposed operational scenarios and design limits. Gene also presented the data system monitor and control interface, which was later seen in action at Goddard on Friday, January 22. Technical issues involving the hardware and software developments are being addressed.

Chuck McClain presented the Calibration and Validation baselines. The baselines incorporate various strategies for meeting the accuracy goals for the water-leaving radiances and chlorophyll-like pigment derived products and include augmentations to MODIS oceans team members (D. Clark for optical buoy and submersible spectrometer development; H. Gordon for atmospheric correction algorithm development; and K. Carder for bio-optical data collection) to accelerate their activities to meet the SeaWiFS launch schedule. The funding profile ramps upward from 1991-1994 and then rapidly decreases in subsequent years, which is supposed to be offset by an increase in MODIS ocean team funding. Other investigators are also being funded to collect additional bio-optical data sets, address specific atmospheric correction issues, participate in the calibration round-robin, and develop level-3 binning algorithms. The in-house effort is focused on pre- and post-launch onboard sensor characterization and calibration methodologies, post-launch vicarious calibration methodologies, engineering data evaluation, ancillary data analysis and quality control, quality control of level-1 to level-3 products (including development of quality mask and flag algorithms), coordination of a calibration round-robin, and *in situ* data acquisition and database development. The importance of augmenting the MODIS Oceans Team optical mooring program was also made.

Bill Barnes discussed the sensor acceptance tests baselines which are derived from the Statement of Work (SOW) that is a part of the contract between NASA and OSC. The SOW contains a set of SeaWiFS performance criteria which have been divided into pre- and post-launch tests. The output from these tests will constitute the baseline whereby NASA will determine whether the data from SeaWiFS meet the system requirements placed on OSC by the government. Parameters to be measured include relative and absolute radiometric accuracy, modulation transfer function, signal to noise, transient response, polarization insensitivity, and numerous other parameters. Prelaunch results will be reviewed by Project personnel at the SBRC Acceptance Review in March, 1993. OSC is required to declare SeaWiFS operational within 30 days after launch. Within 90 days of this event, the Project must make a determination as to whether or not the system is acceptable.

Stan Hooker gave an overview of the Field Validation and Deployment baselines. He presented the observational requirements for SeaWiFS calibration and validation, identified what constituted a full deployment for SeaWiFS calibration, and gave a quick status of *in situ* data collection. Most of the data collection cruises are coming from MODIS investigations, thus, changes in the MODIS budget critically affect the SeaWiFS field effort. The calendar for upcoming field deployments was presented. The more likely launch date in mid-October fell within the launch slip scenarios he presented.

Howard Gordon gave a tutorial on atmospheric correction and the design of the current SeaWiFS algorithm. The absence of African or Asian dust models, sea surface foam, and cirrus clouds was noted. Regional algorithms would be a useful extension, but might require even more computing power beyond what is already a significant cpu need: approximately 9,800 model runs are needed to generate the preliminary lookup tables for atmospheric correction.

Dennis Clark discussed the evolution of MOBY to its present configuration, planned upgrades, and the deployment area off Lanai, Hawaii. The Lanai site was chosen to optimize several parameters: homogeneous water, enhanced survival probability from being in the lee of several islands, low vandalism probability by fishermen and recreational boaters, easy access, emergency response possibilities, and cellular phone coverage. If all goes well the buoy might be moved to the JGOFS Hawaiian Optical Time Series (HOTS) site north of Oahu, which would allow for more complementary data and regular visitation. He also briefly described the Case 1 water optical algorithm from a historic and simulated SeaWiFS spectral response perspective.

Ken Carder described the factors affecting the algorithm for Case 2 waters, including bottom effects, detritus, humics, Gelbstoff, and Raman emission. The first-order problem is to identify where the Case 1 algorithm breaks down and should be transitioned to a Case 2 analysis. A distance of 200 nautical miles from shore is too far, as the

region varies widely and can be close to the coast in upwelling areas.

Bob Evans described his participation in three projects: SeaWiFS, MODIS, and Pathfinder. He presented his data binning, data quality, level-2 program, and data processing activities. He is supplying much of the processing capability required by Howard Gordon and noted that future programming efforts and cpu upgrades are expected to increase current processing rates by a factor of 2-3. The equal-area grid size was shown, and the two alternative definitions of a data day were described in great detail.

Bob Barnes discussed the transfer of radiometric scales to orbit and *in situ* instruments. There are opportunities to perform a more complete characterization of the sensor, including solar calibration. EOS platform calibration may not view the full-phase moon, a difference from SeaWiFS. Bob Barnes discussed the testing plans at SBRC. Filter data was presented in the second notebook distributed for the SeaWiFS Science Team Meeting (Hooker et al. 1993).

Jim Mueller from the Center for Hydro-Optics and Remote Sensing (CHORS) at San Diego State University (SDSU) discussed the radiometric and derived product accuracy goals for SeaWiFS: a) radiometric accuracy of less than 5% absolute (1% relative), b) water-leaving radiance accuracy to within 5%, and c) chlorophyll-like pigment concentrations to within 35% (Case 1 water). He provided an analysis of the first round-robin radiometric calibration, and plans for the next one. He ended his presentation with four outstanding issues:

1. FEL irradiance intercomparisons are not yet internally consistent at the 5% level.
2. Revisit GSFC-SBRC source intercomparisons.
3. Develop and improve the procedures and software for real-time data analysis for future round-robins.
4. Expand participation in the intercalibration process to include foreign and other U.S. laboratories (e.g., the University of Arizona).

Chuck McClain also gave a brief discussion on the quality control effort. The quality control includes evaluation of the ancillary data used for the level-2 processing (surface wind speed, surface pressure, total columnar ozone, and surface relative humidity), evaluation of quality masks (e.g., cloud recognition) and flags (e.g., sun glint), and evaluation of level-2 derived products. Masked data is assigned a constant value and is not processed while flagged data is processed to level-2 derived values but is not incorporated in the level-3 products. The evaluation of the ancillary data is primarily to screen the gridded field received from operational centers, e.g., the Fleet Numerical Oceanography Center (FNOC), the National Meteorological Center (NMC) and the Total Ozone Mapping Spectrometer (TOMS) Project, for spurious grid values, missing values or missing time periods, and bad data files. This

evaluation also includes comparison of the fields with climatological values. The evaluation of the pigment products will use historical data and match-up analyses of simultaneous satellite and *in situ* data. A request was made to the Science Team to provide historical data to the SeaWiFS Project.

Data archive and delivery was presented by Dorothy Zukor of the Goddard DAAC. The top three priorities for the DAAC in FY93 are SeaWiFS, Pathfinder, and UARS. In support of SeaWiFS, the primary goals are: a) maintaining an archive of SeaWiFS data products, b) providing SeaWiFS data to authorized users, and c) providing user services for SeaWiFS data. The connection between the DAAC and SeaWiFS has been strengthened by the *tiger team* of Lola Olsen, Phil Pease, and Eugenié Del-Colle. A description of the appearance of the browse and ordering interface was presented. The DAAC will have a customer service line. There is currently no data pricing policy because the operational time lines imposed on the V0 Goddard DAAC by the SeaWiFS launch precede the planned V0 operational schedule by one year.

### 1.3 Meeting Agenda

#### Monday, 18 January

1800	<i>Registration, Icebreaker with Cash Bar</i>	
1900	Ocean Color Comments	S. Wilson
2100	<i>Evening Adjournment</i>	

#### Tuesday, 19 January

0700	<i>Registration, Continental Breakfast</i>	
0800	Welcome, Logistics	W. Esaias
0810	NASA Headquarters Perspective	D. Butler
0825	SeaWiFS and the NASA Ocean Color Program	F. Muller-Karger
0840	SeaWiFS Within GSFC Perspective	V. Salomonson
0855	SeaWiFS Project Baselines, Status, and Introductions	R. Kirk
0925	Science Goals, Objectives, and Data Products	W. Esaias
0945	OSC and the SeaStar Mission	A. Elias
1000	<i>Break</i>	<i>OSC Pegasus Video</i>
1015	SeaStar Mission Status	K. Lyon
1040	SeaWiFS Sensor Status	R. Roberts
1100	<i>Luncheon</i>	
1230	Agency Introductions	W. Esaias
1235	The Navy Perspective	R. Winokur
1250	The NSF Perspective	M. Reeve
1305	The NOAA Perspective	K. Sullivan
1320	The ONR Perspective	R. Spinrad
1335	The DOE Perspective	G. Saunders
1350	SeaWiFS and MODIS Introductions	W. Esaias
1400	Mission Operations Baseline	W. Gregg
1420	Data Acquisition Baseline	C. Vermillion

1440	Data Processing Baseline	G. Feldman
1500	<i>Break</i>	<i>Lewis P-3 Video</i>
1515	Calibration and Validation Baseline	C. McClain
1535	Acceptance Tests Baseline	W. Barnes
1555	Field Validation and Deployment Baseline	S. Hooker
1615	Atmospheric Correction	H. Gordon
1635	Optical Buoy Time Series	D. Clark
1655	Case 1 Algorithm Baseline	D. Clark
1730	<i>Evening Adjournment</i>	

#### Wednesday, 20 January

0700	<i>Registration, Continental Breakfast</i>	
0800	Introductions	W. Esaias
0810	Case 2 Algorithm Baseline	K. Carder
0830	Processing Software	R. Evans
0850	Transfer of Radiometric Scales to Orbit and <i>In Situ</i>	R. Barnes
0910	Sensor Calibration and Characterization Baseline	R. Barnes
0930	Calibration of Optical <i>In Situ</i> Instruments	J. Mueller
1000	<i>Break</i>	<i>MOBY Video</i>
1030	Quality Control of Data Products Baseline	C. McClain
1050	Data Archive and Delivery Baseline	D. Zukor
1200	<i>Lunch</i>	
1330	Science Team Member Summaries (members shown in <i>slanted type</i> were represented by those shown in parentheses)	
	Session 1: Abbott, Arrigo, Balch, Bidigare, Carrada (Ribera), Esaias, Frouin, Garcia, Halpern	
	Session 2: Aiken, Bishop, Brown, Cota, Doerffer, Falkowski, Fukushima, Glover, Hofmann	
1500	<i>Break</i>	
1530	Science Team Member Summaries <i>cont.</i>	
	Session 1: Davis, Hoge, Kishino, Korotaev, Lewis, Matsumura, Mitchell, Mueller, Shillington, Slater, Sturm, Trees, Walsh, Wernand, Yoder	
	Session 2: Iverson, Kamykowski, Kopelovich, Lara-Lara, Luther, McClain, Morel, Muller-Karger, Sakshaug (Pettersson), Tindale (Stegmann), Unlüata (Saydam), Wastenson (Kahru), Yentsch, Zaneveld	
1800	Plenary to set Working Group Sessions	
1830	<i>Evening Adjournment</i>	

#### Thursday, 21 January

0700	<i>Registration, Continental Breakfast</i>
0800	Working Group Sessions

A: HRPT and Data Policies	Kirk/Davis	1345	GSFC Bus Arrives at Building 28
B: Round-Robin Calibration and Field Deployments	McClain/Mueller	1400	Start of GSFC Tour in Building 28 Room E210 Bus Departs from Building 28 for BWI
C: Data Products and Adding New Products	Esaias/Yentsch	1500	Bus Departs from Building 28 for BWI Bus Departs from OSC for GSFC
D: Atmospheric Correction Algorithms	Gordon	1600	Bus Departs from Building 28 for BWI OSC Bus Arrives at Building 28
1000 <i>Break</i>		1700	Bus Departs from Building 28 for BWI
1030 Working Group Sessions <i>cont.</i>		1800	<i>Tour and Demonstration Adjournment</i> Bus Departs from Building 28 for BWI Bus Departs from Building 28 for Annapolis
A: Open for Impromptu Working Groups	TBD		
B: Open for Impromptu Working Groups	TBD		
C: Algorithm and Product Validation and Binning	McClain/Morel		
D: Atmospheric Correction Algorithms <i>cont.</i>	Gordon		
1200 <i>Lunch</i>			
1300 Working Group Sessions <i>cont.</i>			
A: HRPT Ground Station Technology	Vermillion/Lewis		
B: SeaWiFS Sensor Acceptance and Calibration	Barnes/Gordon		
C: Data Distribution and Access	Zukor/Glover		
D: Open for Impromptu Sessions	TBD		
1500 <i>Break</i>			
1530 Working Group Sessions <i>cont.</i>			
A: SeaWiFS Mission Operations	Gregg/Evans		
B: Optical Protocols Revisions	Esaias/Mueller		
C: Software Policy and Availability	Feldman/Abbott		
D: Open for Impromptu Sessions	TBD		
1730 <i>Dinner</i>			
1930 Working Group Sessions <i>cont.</i>			
A: Open for Impromptu Sessions	TBD		
B: Open for Impromptu Sessions	TBD		
C: EOS Color Mission and White Paper	Esaias/Abbott		
D: Open for Impromptu Sessions	TBD		
2100 <i>Evening Adjournment</i>			

### Friday, 22 January

0700 <i>Registration, Continental Breakfast</i>	
0800 Plenary Introduction	W. Esaias
0810 Working Group Recommendations	W. Esaias
0930 Resume Plenary	
1000 <i>Break</i>	
1015 Resume Plenary	
1130 <i>Annapolis Adjournment</i> <i>Boxed Lunches Served</i>	
1200 Buses Depart for GSFC and OSC Tours	
1245 GSFC Bus Drops Shoppers at Visitor's Center	
1300 GSFC Bus Arrives at Building 28	
1330 GSFC Bus Picks up Shoppers at Visitor's Center OSC Tour Begins	

## 2. PROJECT BASELINES

Project baselines have been presented incrementally in project preliminary design reviews (PDRs), critical design reviews (CDRs), and quarterly element reviews. A synthesis of this information was presented in the first notebook distributed by the Project before the meeting (Hooker et al. 1992). This section is a partial update of the Project baselines and represents the primary responsibilities of each Project element. Note that some of the baselines are subject to extensive revisions as indicated in Sections 3 and 4.

### 2.1 Algorithms

*Issue:* Atmospheric correction and bio-optical algorithms are required for generating level-2 products. These algorithms must be developed based on SeaWiFS wavelengths. The data products must be quality controlled and validated.

*Action:*

- At the instruction of NASA HQ, relevant EOS MODIS ocean team activities have been accelerated to meet SeaWiFS objectives and schedules. These include contracts with the following:
  - the Moss Landing Marine Laboratory (MLML) to provide a shipboard radiometer, to build and maintain a calibration buoy (two instrumented optical buoys and a deep-sea mooring), and to provide near-real time buoy data sets;
  - the University of Miami (UM) to provide operational atmospheric corrections; and
  - the University of South Florida (USF) for bio-optical data sets and Case 2 algorithm development through a cooperative agreement.
- In order to ensure *in situ* optical data sets are comparable and of high quality, a calibration round-robin has been initiated.
  - A contract to SDSU for instrument calibrations and round-robin coordination has been negotiated.
  - The first round-robin was held in July 1992.



- c) The National Institute of Standards and Testing (NIST) has been funded to participate in the round-robin and to provide a transfer radiometer which can be circulated to participating laboratories to track calibration sphere characteristics.
  - d) GSFC will maintain a calibration scale and conduct sphere calibration comparisons at SBRC.
3. The SDSU contract and additional cooperative agreements with Scripps Institution of Oceanography (SIO) and the University of California at Santa Barbara (UCSB) augment ongoing bio-optical field programs in order to broaden the bio-optical data collection program.
  4. A bio-optical database is being designed at GSFC which will incorporate historical data sets and all data sets provided by NASA funded investigators as well as data volunteered by others. The database will be accessible to approved investigators for algorithm development following guidelines established in the *In Situ Data Policy* (see Appendix A).
  5. Operational atmospheric and bio-optical algorithms will require the approval of the Science Team. When more than one algorithm is available, the SeaWiFS Project will conduct an intercomparison, document the results, and provide the results to the Science Team.
  6. In the case of data quality masks for level-2 processing and level-3 product generation, the Project will evaluate mask parameters and algorithms. Present masks include flags for clouds, sensor ringing, sensor tilting, sun glint, anomalous 550 nm normalized water-leaving radiance, and anomalous epsilon values.
  7. Product validation will include the comparison of field observations and the satellite derived values (match-ups) as field data are received.
3. Problems associated with these sensors include:
    - a) Nimbus-7/TOMS remains operational, but calibration is a concern;
    - b) Meteor/TOMS data are severely compromised by the non-sun synchronous orbit; and
    - c) The Pegasus/TOMS launch has slipped to late 1994.
  4. Problems associated with products from these sensors include:
    - a) The daily mean NOAA/TOVS ozone products are available from NMC, but are formatted to a coarse grid;
    - b) Pathfinder/TOVS products have a high resolution and separate fields for the 0730 and 1930 passes are generated, but the reprocessing schedule does not match the SeaWiFS operational requirements.
  5. Nimbus-7/TOMS ozone products are being routinely collected by the Project. An agreement between NMC and GSFC Code 900 is being negotiated which would allow access to the gridded TOVS ozone products.
  6. Surface wind speed, relative humidity and pressure fields are available from NMC and are identified in the GSFC-NMC agreement.
  7. Surface wind speed, water vapor pressure, air temperature, and pressure are available from FNOC. An agreement with FNOC to routinely copy these products has been finalized.
  8. All ancillary data sets will be reformatted to the Hierarchical Data Format (HDF) at the original time and space resolution and then transferred to the GSFC DAAC for distribution.

## 2.2 Ancillary Data

**Issue:** Certain ancillary data are required for atmospheric correction of SeaWiFS level-1 data. The parameters and data sources must be identified and operational data capture arrangements negotiated. Access to the data sets by the research community must be provided.

**Action:**

1. To date, the meteorological fields required for the atmospheric correction include total ozone concentration, surface pressure, surface wind speed, and relative humidity.
2. Various ozone data sources have been explored. Routine observations of global ozone concentration are made by the following sensors: TOMS, and the Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS).

## 2.3 Data Quality and Acceptance

**Issue:** The SeaWiFS data quality and characteristics are to meet certain specifications as defined in the contract with OSC. Plans to determine whether or not the observations are within specifications need to be defined and contingency plans made in case the data fail to meet specifications at any time during the mission.

**Action:**

1. The instrument build has been closely monitored by SeaWiFS personnel who have made routine visits to SBRC to consult on the design and characterization of the instrument optics, electronics, and engineering data system components. This interaction has been very open and constructive and has provided the SeaWiFS Project with the opportunity to make recommendations and gain a detailed knowledge of the instrument. The knowledge gained has been preserved in the form of numerous memorandums and reports to the Project management. This information is being

condensed and published in the *SeaWiFS Technical Report Series*.

2. The Project will receive a comprehensive suite of digital prelaunch test, calibration, and characterization data which will be described in the *SeaWiFS Technical Report Series* and maintained in the Project's databases.
3. All engineering data (18 parameters) will be monitored in near-real time and archived in the Project's databases.
4. The Project has developed a data certification matrix which outlines the pre- and post-launch tests required to certify the contractual data quality.
5. Scenarios for handling various sensor problems, e.g., detector failure, are being developed.
6. The integrated sensor, data, and telemetry subsystems will undergo an engineering and radio frequency (RF) compatibility test in the April 1993 time frame. This is an end-to-end test including links through Wallops Flight Facility (WFF), NASA Communications (NASCOM), SeaWiFS Data Capture, and the SeaWiFS Data Processing System (SDPS).

## 2.4 Level-3 Binning

**Issue:** Level-3 binned data products will provide global data sets of SeaWiFS derived products at reduced resolution for a number of time scales. The binning methodologies need to be defined.

**Action:**

1. In high latitude areas where orbit overlap occurs, valid data from all orbits will be binned in the daily products. An orbit selection algorithm may be developed after launch based on the study of actual data.
2. If an Earth area is resampled in the same orbit as a result of tilting the sensor, the data from the tilted sensor will be used. That is, the tilt to avoid glint contamination is more critical than a smaller atmospheric path length. Moreover, if tilt data are missing (e.g., dropout lines), they should not be replaced with non-tilt data so as to not mix the two types of data in the product. The calibration and validation group will study the differences in these overlap areas after launch for possible modification of this recommendation.
3. All parameters calculated for level-2 archive products will be binned except the epsilon values. This includes 8 radiances, a CZCS-type pigment, chlorophyll *a*, and  $K(490)$ . In addition,  $[chl. a]/K$  is being recommended as a level-3 product related to productivity in response to suggestions for such a product voiced at the Prelaunch Science Working Group meeting in August 1991.

4. A bin-based field will be used to indicate the time distribution of data within a bin.
5. Level-3 data products will be created with one geophysical parameter per file. For binned products, another file containing common bin-based data will also be created. During distribution, the common data file will need to be sent with any order of a binned product, regardless of which parameters are requested.
6. For each bin, the number of pixels binned ( $N$ ) and the sum of the square roots of daily  $N$ s will be accumulated. For each geophysical parameter, the sum of the daily square roots of  $N$  times the daily geophysical values and the sum of those values squared will be accumulated. (Note:  $N$  is stored for informational purposes only, not for computation.) The daily geophysical values will be the sum of the natural logarithms of the binned data. The accumulated values will permit the maximum likelihood estimator (MLE) to be calculated.
7. The common bin data are comprised of the bin index, the number of pixels binned, the number of scenes contributing to that bin, the sum of the square roots of daily  $N$ s, and the time field.
8. The geographical limits of the binned files should conform to that of either the Pathfinder sea surface temperature group or of the International Satellite Cloud Climatology Project (ISCCP) data.
9. A modified ISCCP scheme with 5,940,426 equal-area bins (approximately 81 km<sup>2</sup>) will be used for the binning grid.
10. Daily, monthly, and yearly binned products will be produced. In addition, a product representing a near weekly period will be produced. This is the same as for Advanced Very High Resolution Radiometer (AVHRR) sea surface temperature level-3. In addition, an 8-day product will be produced, running sequentially from January 1 of each year.

## 2.5 Data Processing and Software

**Issue:** The data processing issue is comprised of three parts: a) software required to produce standard SeaWiFS products must be available to the Science Community; b) the proposed distribution mechanism for SeaWiFS software via the Earth Observing Satellite Data Information System (EOSDIS) Science Processing Library is no longer available; and c) there is no group within the SeaWiFS Project tasked or funded with supporting software distribution to the Science Community.

**Action:**

1. Software to produce standard SeaWiFS level-1 data in HDF format from level-0 (HRPT data) will be developed by the Data Capture Group of the SeaWiFS

Project and will be supported on VAX, PC, and UNIX computer systems.

2. Specific modules within the UNIX version of SEAPAK currently under development will be the distribution vehicle for SeaWiFS software. In particular, the following functions will be supported:
  - a) Level-0 to level-1 conversion,
  - b) Level-1 to level-2 processing including bio-optical and atmospheric algorithms used to produce the standard SeaWiFS products,
  - c) Level-2 to level-3 binning procedures, and
  - d) Level-3 binned to level-3 standard map procedures.
- 3) These modules will be distributed as both source and executable code by the GSFC EOSDIS V0 DAAC with the appropriate code and procedure documentation. The DAAC will provide the first line of response for questions with direct access to the appropriate individuals within the SeaWiFS and SEAPAK groups when necessary. In addition, UNIX SEAPAK will also be available directly from the SEAPAK development group.
- 4) Project developed software and documentation will be available on request, however, the SeaWiFS Project is not prepared to support the implementation and integration of this software at other sites.

## 2.6 Data Archive and Delivery

*Issue:* The Goddard V0 DAAC will provide a mechanism for authorized users to search, browse, and order SeaWiFS data products. In addition, the DAAC will provide all users access to the SeaWiFS Inventory.

*Action:*

### 1. On-line functions:

- a) Inventory search and results will provide access to the inventory of all Goddard DAAC-held SeaWiFS data:
  - GAC level-1a,
  - LAC level-1a,
  - GSFC/HRPT LAC level-1a,
  - GAC level-2,
  - GAC level-2 browse,
  - GSFC/HRPT LAC browse,
  - GAC level-3 binned,
  - GAC level-3 daily, weekly, monthly, and annual standard mapped,
  - GAC level-3 browse, and
  - Ancillary.
- b) Inventory Search and Results will be implemented within both an alphanumeric and graphical environment with the following features:
  - Search capability provided for generic meta-data: data set name, data product name, sensor, platform, parameter (general and specific), temporal coverage, and spatial coverage;
  - SeaWiFS-specific search parameters also supported;
  - On-line help;
  - Dependent valids;
  - Non-hierarchical;
  - Support for user profile (enter and update personal information and preferences: name, affiliation, address, phone, format preferences, etc.);
  - Support for coincident data search (e.g., SeaWiFS LAC level-1a and ancillary data); and
  - Mechanism for accessing detailed Guide information on SeaWiFS data [integration with the EOSDIS Information Management System (IMS) for inter-DAAC interoperability will be available after July, 1994, including access to detailed SeaWiFS product information through the Guide function].
- c) Browse:
  - Browse will be restricted to authorized users only.
  - SeaWiFS browse images will be in HDF.
  - Minimum browse support will be electronic File Transfer Protocol (FTP) browse:
    - i) The researcher orders a browse image with the Product Request function;
    - ii) The browse image is provided via FTP;
    - iii) The researcher uses local tools on a home workstation for viewing the browse images; and
    - iv) The local browse tools will allow user to send order message to DAAC.
  - Integrated browse may be available for SeaWiFS data:
    - i) The Graphical User Interface (GUI) will require user access on-line functions with a UNIX system running X-Windows;
    - ii) The browse function is integrated with Inventory Search and Results and Product Request functions;
    - iii) The user interactively requests a browse image while viewing search results and before ordering; and
    - iv) The user can superimpose maps, granule coverages, longitude and latitude (i.e.,  $x,y$ ) grids, and browse images on one screen.
- d) Product Request
  - Product Request will be restricted to authorized users only;

- Both an alphanumeric user interface and a GUI will be available with the following features:
  - i) Integrated with Inventory Search and Results function;
  - ii) User selection of standard distribution media supported: 9-track, 8 mm, 4 mm, and limited FTP network transfer;
  - iii) Ordering capability for software generated by SeaWiFS; and
  - iv) Pricing policy is in a draft form.
- 2. Primary off-line function is User Support Office support available via phone, fax, postal, or electronic mail (e-mail).
- 3. Behind-the-scenes functions:
  - a) Oracle and database installed (data dictionary in place);
  - b) Commercial off-the-shelf (COTS) software purchased: IDL, UIM/X, CodeVision (a debugger), JYACC application manager (JAM) software in use for user interface;
  - c) Meta-data loader completed (in testing);
  - d) Scheduler in design;
  - e) Granule to file mapping completed;
  - f) Unitree file management system in procurement;
  - g) Data transfer utility completed (in testing);
  - h) Cygnet jukebox received;
  - i) Network analysis in progress;
  - j) Independent acceptance testing in progress;
  - k) System upgrades: additional disks, peripherals, and memory as well as uninterruptable power systems (UPSs);
    - DAAC Staff Interface accomplished the following:
      - i) Completed the Request Tracking and Staff Usage System,
      - ii) Developed a *help* text and a *help* text editor,
      - iii) Currently the Request Tracking Interface is receiving requests from the IMS and simulating the processing of the request,
      - iv) Currently being ported to the SGI 4D/35 (EOSDEV1) from the HP,
      - v) Developed GUI version of Software Modification Request which allows all information and queries to be performed from one screen, and
      - vi) Implemented a *smart* meta-data update system for most meta-data tables.
- 4. DAAC Software Development/Analysis and Data Delivery for SeaWiFS:
  - a) The DAAC is supporting SeaWiFS requests for correlative data, implementing these data into a format directly usable by existing analysis programs. Other correlative data sets will be transferred to SeaWiFS as they are converted to HDF in the DAAC.
  - b) Progress continues on:
    - Analysis of SeaWiFS data product implementations in HDF,
    - Development of DAAC data ingest software for SeaWiFS data products, and
    - Compilation of SeaWiFS Data Dictionary as per DAAC Meta-data Submission Guidelines.
- 5. Open issue: currently assessing HRPT support requirement to provide meta-data and Guide information within Goddard DAAC inventory for data held by NASA approved HRPT stations.

## 2.7 Data for Bio-Optical Algorithms

*Issue:* *In situ* data are needed to develop a comprehensive archive of high quality data suitable for bio-optical algorithm development and product validation.

*Action:*

1. Participation in NASA sponsored cruises for greater spatial resolution in areas of differing variability:
  - a) EOS/MODIS development cruises, and
  - b) System initialization and certification cruise (tied to launch).
2. Augmentation of approved field experiments to expand the emerging database:
  - a) JGOFS Bermuda time series (D. Siegel),
  - b) California Cooperative Fisheries Institute (Cal-CoFI) cruises (G. Mitchell), and
  - c) Navy Case 2 cruises (J. Mueller).

## 2.8 Data for Vicarious Calibration

*Issue:* *In situ* data are needed to develop a comprehensive archive of the highest quality data possible for vicarious satellite calibration and for monitoring long-term sensor stability.

*Action:*

1. Deployment of an optical buoy (MOBY) for maximum temporal resolution in oligotrophic water with minimal spatial variability. The current deployment site will be to the west of Lanai, Hawaii.
2. Participation in NASA sponsored cruises for:
  - a) System initialization and certification in Case 1 water, and
  - b) Intermittent calibration points to check on sensor calibration.

3. Support of a calibration round-robin for:
  - a) Laboratory source verification (CHORS, NIST, GSFC, UCSB, UM, and NOAA),
  - b) SeaWiFS calibration transfer (SBRC and GSFC),
  - c) *In situ* radiometer calibrations (2–4 per year with options).

## 2.9 Launch Slip Contingency

*Issue:* Given the complexity of a satellite launch, the field deployment strategy must accommodate launch slips.

*Action:*

1. Ensure each optical buoy refurbishment cruise can be promoted to an initialization and certification cruise.
2. Schedule the cruises closest to launch with groups or organizations that have the most scheduling flexibility, so they can be rescheduled if need be.
3. Provide a deployment strategy that maximizes every data collection opportunity—each cruise contributes significantly to the SeaWiFS *in situ* database.
4. Communicate launch status on the SeaWiFS bulletin board.

## 2.10 Ground Station Support

*Issue:* In view of the large number of possible SeaWiFS data users around the world, the SeaWiFS Project has been directed to provide as much support as possible to NASA sponsored users. Under this directive, software and specification items provided by the GSFC Ground Station to NASA sponsored HRPT users will be available to the community.

*Action:*

1. Specify ground station design and hardware. On-site support will be on a case-by-case basis and will include data format support and ingest specifications.
2. Provide software to enable four computer platforms to read and write 4 mm digital audio tape (DAT) interchangeably. The supported platforms will be SGI, SUN, VAX, and PC.
3. Provide software to convert level-0 (frame formatter output) to level-1a (F. Patt's specifications). It will be available on the same four platforms above.
4. HDF format software support. This will be the final data format before storing onto 4 mm tape, if it is to be sent to NASA. This format will be supported for the same four platforms above.
5. SeaWiFS orbit prediction model. Source code and executables will be provided and supported for the four platforms above.
6. All source code and executables will be provided to the users via the SeaWiFS bulletin board on Omnet or on other media on a case-by-case basis.

## 2.11 Navigation Accuracy Contingency

*Issue:* One pixel navigation accuracy not achieved.

*Action:* 1) Attempt to use processed attitude sensor data instead of onboard computed value, 2) use spacecraft and instrument telemetry to determine correlations of inaccuracies with sensor and spacecraft behavior, and 3) make limited corrections using manual methods.

## 2.12 Power Limitation Contingency

*Issue:* Power limitation.

*Action:* Specifically, assess the power trade-off scenarios, e.g., reduce GAC coverage on one orbit to enable solar calibration. Generally, follow the overall prioritization policy:

1. GAC coverage;
2. LAC data for calibration activities:
  - a) detector analysis,
  - b) *in situ* support,
  - c) lunar calibration,
  - d) inter-gain calibration,
  - e) solar calibration, and
  - f) navigation analyses.
3. Other science requests for LAC data.

## 2.13 Loss of Tilt Contingency

*Issue:* Loss of tilt control.

*Action:* Assess capabilities to obtain inter-gain calibrations and detector checks without tilt. Eliminate solar calibration and increase reliance and frequency of lunar calibrations.

## 2.14 Detector Failure Contingency

*Issue:* Detector failure on-orbit.

*Action:* Execute an immediate detector check in real time commanding mode, locate the faulty detector, and upload a new detector sequence during the next pass.

## 2.15 Orbital Altitude Contingency

*Issue:* Orbital altitude too high or low (by 100 km), or elliptical.

*Action:*

1. Too low—increase level-3 grid size.
2. Too high—reduce recording time near poles to take advantage of overlap.
3. Elliptical—increase level-3 grid size and manage the recorder to obtain global coverage.

## 2.16 Orbit Contingency

*Issue:* Non-sun synchronous orbit.

*Action:* Change the altitude to achieve a sun synchronous inclination; otherwise, take no action and accept a serious reduction in mission goals.

## 2.17 Equator Crossing Contingency

*Issue:* Equator crossing time off local noon.

*Action:* No action taken. There is very little impact if within one hour of noon.

## 2.18 Real-Time Data Access

*Issue:* The SeaWiFS Project must provide real-time support for data it holds. The DAAC will hold data older than the embargo period.

*Action:*

1. Respond as detailed in the *Dear Colleague Letter*: who, why, when, and how.
2. Approval by the Project and HQ is required, but access must be limited.
3. Approved near-real time investigators placed on quick access list and users notified.
4. Getting GSFC data:
  - a) Recorded GAC, LAC, and HRPT LAC granules will be put in a password-protected directory for intermediate or final user to access via FTP, etc.
  - b) Required level-1, level-2, level-3, and ancillary data, as soon as available.
  - c) No customized products presently planned.
5. Getting non-GSFC data from NASA approved stations:
  - a) Arrangements will be made between the principal investigator and the HRPT station, and
  - b) Fees are to be for marginal costs only.
6. Getting commercial station data: pay the price.
7. Alternatives and improvements to GSFC support:
  - a) Subsample and/or compress certain files (file size, compression, and subsampling TBD),
  - b) Adopt a real-time capability similar to that developed at the UM Rosenstiel School of Marine and Atmospheric Sciences (RSMAS), and
  - c) Arrange with someone to provide such a capability.

## 2.19 Optical Protocols

*Issue:* The *Ocean Optics Protocols for SeaWiFS Validation* (Mueller and Austin 1992) requires revision in certain areas. (This will inevitably occur in the future as new

techniques are developed and recommended protocols are evaluated.)

*Action:*

1. Identify areas of concern.
2. Known areas of concern:
  - a) Improve saturation levels which are thought to be too low (D. Siegel).
  - b) Develop methods for calculation of derived properties:  $K_0(\lambda)$  and  $L_{WN}(\lambda)$ .
  - c) Elimination of instrument self-shading.
  - d) Avoid ship shadowing (D. Siegel).
  - e) Make improvements to round-robin techniques.
  - f) Obtain more detail on airborne measurements.
  - g) Improve protocols, which are too hard and expensive.
3. Reconvene a NASA *in situ* optics working group in the Spring of 1993 to address needed changes.
4. Issue a revised technical report or reports in the *SeaWiFS Technical Report Series* as required.

## 2.20 Data Products

*Issue:* The SeaWiFS project must deliver both at-launch and new data products to the Science Community. In order to produce the best standard products possible, new or modified algorithms must be developed.

*Action:*

1. At-launch data products to be produced:
  - a) Level-1a:
    - Satellite and calibration data;
    - 694 Mbytes/day or 253 Gbytes/year; and
    - Granule is orbit segment of constant tilt command.
  - b) Level-2:
    - 13 products: 8 radiances, 1 pigment, 1 chlorophyll *a*, 1  $K(490)$ , 1 epsilon map, 1 quality mask;
    - 461 Mbytes/day or 168 Gbytes/year; and
    - Granule is same as level-1.
  - c) Level-3 Binned:
    - 9 km spatial bins (equal area);
    - 1 day, 8 day, 1 month, 1 year time bins;
    - 263 Mbytes/day or 93 Gbytes/year; and
    - Granule is global, time period.
  - d) Level-3 Standard Mapped:
    - 4 parameters mapped onto linear lat-lon grid;
    - 1 day, 8 day, 1 month, 1 year time scales; and
    - 41 Mbytes/day or 18 Gbytes/year.
  - e) Browse Products:

- For level-2 and level-3 products;
  - 0.5 Mbytes/day or 182 Mbytes/year; and
  - One browse image per granule.
- f) Ancillary Data:
- In form used for level-2 products; and
  - 5 Mbytes/day or 2 Gbytes/year.
2. Use 180° in longitude to delineate days.
3. New candidate products: a) daily incident irradiance photosynthetically available radiation (PAR) level-3 (J. Bishop), and b) Level-3 [*chl. a*]/K (J. Campbell).

## 2.21 *In Situ* Data Policy

**Issue:** Accurate *in situ*, shipboard, and airborne measurements must be made rapidly available to Science Team members and other approved investigators for advanced algorithm development and data product validation purposes. The investigator providing the data must receive proper credit and acknowledgement for the considerable expertise and effort applied to obtaining and reducing the data.

**Action:**

1. Submission:
  - a) Data obtained under contract must be submitted with proper calibration information not later than 6 months from collection.
  - b) Science Team members and other investigators making suitable observations must submit their data no later than one year following collection, or at the time of publication, whichever is sooner.
  - c) Investigators making observations of bio-optical parameters are expected to submit their observations prior to accessing data from others.
2. Access:
  - a) Limited access to approved users for a period of one year following the collection of the data.
  - b) Unlimited access to data following an agreed upon period.
  - c) Records of distribution will be maintained and forwarded to the provider, and citation requirements set forth below still apply.
  - c) Only information about the digital data (parameters, locations, dates, investigators, etc.) will be available for unlimited downloading or distribution.
3. Use Conditions:
  - a) Users of the data must provide proper credit and acknowledgement of the provider (name, works, data archive).
  - b) Users utilizing any data are required to give all providers of the data a copy of any manuscript resulting from any use of the data.

- c) Within one year of data collection, the provider(s) shall be offered the right to be a named co-author.
4. Updates and Corrections:
  - a) The Project will maintain a record of updates and corrections.
  - b) Summaries will be posted on the SeaWiFS bulletin board.
5. Formats:
  - a) Data will be provided in an agreed upon format.
  - b) Parameters and units shall be as described in the *Ocean Optics Protocols for SeaWiFS Validation* (Mueller and Austin 1992).
  - c) Data values will be in geophysical units.
  - d) High level data sets are encouraged. Descriptions of, or citations of, procedures used to derive the values are required.
  - e) Data should be segmented into rational sets, by station, date, parameter, etc.
  - f) Data quality, calibration traceability and history, drift, and sampling protocols may be in text format. A list of what criteria need to be treated will be developed by the Science Team.
6. Record Keeping:
  - a) The Project will maintain an accurate database of these data. All data will retain the investigator's identification, along with any necessary quality control information, at the level of distribution.
  - b) The Project will maintain accurate records of distribution and will inform the original provider of investigators requesting their data.
  - c) The data will not be released for inclusion in other databases which do not agree to honor the conditions set forth above.

## 3. RECOMMENDATIONS

The Science Team and invited audience had many responses to the Project baselines. This section summarizes the suggestions promoted during plenary sessions or in smaller working groups. Although participation in the working groups was voluntary, the Project presented a draft schedule to the plenary which was then modified to minimize attendance conflicts and maximize participation. At the conclusion of the working group sessions several were determined to be important enough to require additional meetings. The preliminary composition of these more permanent working groups is given in Table 1.

### 3.1 Sensor Acceptance and Testing

1. Review the baseline calibration and characterization requirements. If satisfactory, obtain test data in digital form (disk).

**Table 1.** Preliminary SeaWiFS Working Groups and their members.

<i>Bio-optical Algorithms</i>	<i>Calibration Group</i>	<i>Atmospheric Correction</i>	<i>Round-Robin Protocols</i>	<i>Primary Productivity</i>
J. Aiken W. Balch K. Carder D. Clark† W. Esaias H. Gordon F. Hoge S. Hooker M. Kishino C. McClain† G. Mitchell A. Morel J. Mueller F. Muller-Karger D. Siegel R. Smith C. Trees C. Yentsch J. Yoder	R. Barnes W. Barnes W. Esaias R. Evans H. Gordon C. McClain† J. Mueller P. Slater†	W. Esaias R. Frouin H. Fukushima H. Gordon† W. Gregg† C. McClain A. Morel	D. Clark R. Doerffer W. Esaias† H. Gordon F. Hoge S. Hooker M. Kishino O. Kopelovich M. Lewis C. McClain G. Mitchell A. Morel J. Mueller† D. Siegel R. Smith R. Zaneveld	W. Balch R. Bidigare W. Esaias† P. Falkowski† R. Iverson D. Kamykowski M. Lewis C. McClain G. Mitchell A. Morel F. Muller-Karger C. Yentsch

†Chairman

†Co-chairman

2. Examine SeaWiFS test results to date.
3. Determine adequacy of testing program. There may be a system level thermal vacuum (TV) test (i.e., SeaWiFS and SeaStar) at GSFC.
  - a) Recommend a radiometric calibration after the second TV.
  - b) Recommend covering diffuser opening and including diffuser witness sample in the second TV.
4. Procedure for changing sensor calibration:
  - a) determination of change,
  - b) comparison of different calibration techniques,
  - c) determination of when correction is required, and
  - d) procedure for implementing change.
5. Form a Calibration Team and change calibration values only when recommended by the Calibration Team.
6. Transfer calibration scale to orbit. Recommend solar measurements at SBRC with good measurements of diffuse and direct sky radiance, and atmospheric transmissivity (see P. Slater).
7. Solar irradiance data sources. Not a problem; solar variations are very small.

### 3.2 Ocean Optics Protocols

Items 1–4 are immediate and accepted changes to be promulgated by memorandum:

1. Increase saturation irradiance to  $300 \text{ mW cm}^{-2} \text{ sr}^{-1}$ .  
Jim Mueller will revise Table 5 in the *Ocean Optics*

*Protocols for SeaWiFS Validation* (Mueller and Austin 1992) accordingly and circulate the revisions for comment by the community.

2. Channel recommendations for in-water  $E_d$ ,  $E_u$ , and  $L_u$ :
  - a) Change SeaWiFS band 5 to 555 nm versus two channels at 550 and 560 nm.
  - b) Reconsider any possible phycoerythrin influence in a Summer 1993 revision to the protocols.
3. Add recommendations to avoid ship induced turbulence when maneuvering on station, especially in Case 2 waters.
4. Adopt a C8 high performance liquid chromatography (HPLC) technique for algorithm development and validation and recommend that a suitable C8 reverse phase HPLC method be used to provide a baseline separation of monovinyl and divinyl chlorophyll *a* for the purpose of calculating total chlorophyll *a* concentration.
5. Topics recommended for revision in a Summer 1993 workshop:
  - a) Develop specific protocols for determining  $K(\lambda)$  (for bio-optical algorithm development and validation) and for propagating  $L_u(z, \lambda)$  to  $L_{WN}(\lambda)$ .
  - b) Encourage new research to experimentally verify H. Gordon's instrument self-shadowing model, and develop detailed correction protocol.
  - c) Develop protocols to test for ship shadow influence and revise ship shadow avoidance protocols as appropriate.



- d) Develop more specific protocols for airborne radiometry.
- e) Develop detailed protocols for algorithm development and validation in Case 2 waters.

### 3.3 Data Products

#### Recommendations:

1. Save data over land at level-1; only lakes and large rivers at level-2.
2. Level-3 binned preferred option is comprised of 6 total files: 4 parameter files [pigment, chlorophyll *a*, *K*(490), and 1 TBD], 1 file with all 8 radiances, and 1 file with all statistics.
3. Lossless compression of data must be considered where appropriate.
4. The Project needs to pay attention to requirements for handling special requests and problems, i.e., international concerns. Is an additional person needed to fulfill these needs required?
5. Regional products should be made available via subsetting by the DAAC; emphasis should be on using HDF tools and cpu requirements, not data storage. (Note: HDF's ability to permit subsetting was one of the features that figured heavily in the decision to adopt HDF as the standard data format for SeaWiFS products.)
6. Level-3 standard mapped products are of much use to the scientific community and should be kept at present size ( $4096 \times 2048 \times 10$ ).
7. The proposed method for adding or modifying algorithms was approved in principle. Minor revisions will be made by W. Esaias and C. Yentsch to include subcommittee and Science Team review. A revised copy will be forwarded to the SST, DAAC, and NASA HQ (a current version is presented in Appendix B).
8. Algorithms for new products should be published:
  - a) Publish short articles in journals such as *Geophysical Research Letters* as soon as available.
  - b) The *SeaWiFS Technical Report Series* should be used for publishing, especially for detailed documentation not suitable for peer reviewed articles.
9. After launch, plug-in modules for new potential algorithms should be placed into the DAAC interface.

### 3.4 New Data Products

Several new data products were discussed. They are presented below along with the PIs who advocated their inclusion:

Product: Daily  $I_0$   
 Originator: J. Bishop  
 Level: Level-3 Only

Rationale: Required for calculation of primary productivity and development of primary productivity algorithms.

Product:  $[chl. a]/K$   
 Originator: J. Campbell  
 Level: Level-3 Only

Rationale: Important in the calculation of primary productivity; must be calculated at the original resolution and binned (can't be calculated from averaged values).

Product:  $\tau_a$   
 Originator: H. Gordon  
 Level: Level-2 and Level-3

Rationale: Important in air-sea interaction, aerosol studies, and  $I_0$  calculation. Currently calculated, but not saved.

Product: Coccolithophores/ $CaCO_3$   
 Originator: W. Balch  
 Level: Level-2 and Level-3

Rationale: There exists a need for a specific algorithm for measurement of the abundance of coccolithophores. The presence of these highly reflective organisms in the surface waters of the oceans causes problems in the determination of phytoplankton pigments by satellite colorimetry. However, there's a need to know the abundance and distribution of these organisms because of the important role they play in calcification, changes in the ocean's albedo, and the air-sea sulfur flux.

Product: Daily Productivity  
 Originator: P. Falkowski  
 Level: Level-2 and level-3

Rationale: This product is of major scientific importance. It requires some research and testing with SeaWiFS data, in terms of approach, ancillary products, methodology, and the like. It is expected that a product will be ready in two years (1995).

Product: Temperature  
 Originator: C. Yentsch  
 Level: Level-3 Only

Rationale: This product should be available from the Jet Propulsion Laboratory (JPL) DAAC. If not, it should be established as a new SeaWiFS product.

Product:  $\Delta pCO_2$   
 Originator: J. Aiken  
 Level: Level-2 and Level-3

**Rationale:** During certain times of the year and in certain regions, a linkage between  $\Delta p\text{CO}_2$  and chlorophyll (and thus productivity) exists, indicating that such an algorithm may be possible. This needs considerable research.

**New products recommendations:**

1. The prioritization for adding these products is in the order they are presented above.
2. The first 3 products listed above are very mature and well defined, and should be added as standard products in principle, as soon as possible.
3. The principal investigator (PI) should work quickly to develop justification and documentation along the lines given in the recommended procedures.
4. The Project and the DAAC should begin immediately to determine the resources needed to implement these products. (The  $I_0$  product may be calculated by the PI, forwarded to the Project for proper formatting, and ingestion by the GSFC DAAC. The second two are produced by the Project.)
5. We expect additional products will become available through the life of the mission.

### 3.5 Algorithm and Product Validation

1. For chlorophyll-like and pigment algorithms:
  - a) 3 channels (non-switching),
  - b) Do not use logarithms for regressions (i.e., do not regress logs vs. logs to get coefficients),
  - c) Use normalized water-leaving radiances,
  - d) Use CZCS Nimbus Experiment Team (NET) team data,
  - d) Develop a quality flag for turbid Case 2 water, and
  - f) Reprocess CZCS pigment in the same way, using the above flag to identify turbid Case 2 waters.
2.  $K(\lambda)$  algorithm:
  - a) Use Austin and Petzold (1981), and
  - b) C. Trees to provide copies of R. Austin's report.
3. Historical databases:
  - a) Optics community to follow recommendations from the International Association for the Physical Sciences of the Ocean (IAPSO), and
  - b) Biochemistry community to follow JGOFS recommendations.
4. Will pursue JGOFS distributed database concept.
5. Level-3 binning algorithm:
  - a) Accept R. Evans' recommendation on spatial day definition, and
  - b) Accept J. Campbell's recommendations on binning statistics (further analyses suggested).

### 3.6 Data Access and Distribution

1. *Data Pricing:* EOSDIS and NASA HQ should supply SeaWiFS data to investigators free of charge until an equitable charging scheme can be determined. Presumably, a PI's computational resources pose a strong and practical control against frivolous orders.
2. *GSFC DAAC Survey:* Every SeaWiFS investigator is strongly urged to fill out and return the questionnaire to Lola Olsen. A copy of the questionnaire can be found in the *Distributed Active Archive Center* section of Vols. 1 and 2 of the SeaWiFS Science Team Meeting Notebooks (Hooker et al. 1992 and 1993, respectively).
3. *IBM RISC Stations (RS-6000):* The GSFC DAAC FTP browse software, which is based on X-Windows, should be supported on IBM RISC workstations (including full source code support), since the Goddard Institute for Space Studies (GISS) is entirely IBM RISC equipped. This would bring the number of supported computer platforms to 5 (SUN, SGI, IBM, HP, and DEC).
4. *Subsetting:* The GSFC DAAC should begin working with NASA HQ to identify a source of funds that will allow the DAAC to implement subsetting algorithms. The subsetting could be part of the user profile and be a standing order, or the parameters for subsetting could be entered when the user places an order.
5. *Data Compression:* Data compression of browse images is desired to facilitate network transfer. Losses are acceptable for browse, but not for real data.
6. *V1 Transition:* The transition to V1 DAAC should be transparent to the science community. V1 personnel should begin working with V0 activities immediately to assure continuity.

### 3.7 Software Policy and Availability

Major Points agreed upon:

1. The primary responsibility of the SeaWiFS Project is to produce scientifically credible data products.
2. SeaWiFS scientific modules will be incorporated into a simplified package which will initially provide level-1 to level-3 processing capability.
3. These modules will be distributed both as source and executable code by the GSFC DAAC and from the SEAPAK group.
4. The DAAC will direct technical questions about the software to the SEAPAK support group.
5. Software will be distributed via all media and transfer mechanisms supported by the DAAC.
6. This package will be supported initially on two computer platforms (SGI and SUN). HPs are used by some investigators and are currently unaddressed. Support should be added and the suggestion is that NOAA,

NASA, and the Monterey Bay Aquarium Research Institute (MBARI) address this need.

7. Software will be distributed to all requestors based on an as yet to be determined NASA Headquarters policy for U.S. and international investigators.
8. Software developed by the Project for its operational data system should also be made available based upon the criteria defined above, although support for these modules would be very limited.
9. It was recognized that software support may be required for as much as 6 months after the release of a new operating system to ensure distributed modules will maintain full functionality.

### 3.8 Atmospheric Correction

1. Atmospheric correction algorithm development issues:
  - a) System requirements for operational algorithm,
  - b) Definition of the error field,
  - c) Provision for a CZCS-class atmospheric correction,
  - d) Dust correction,
  - e) Sun glint correction,
  - f) 765 nm oxygen correction,
  - g) Whitecap correction, and
  - h) Volcanic aerosol corrections.
2. SeaWiFS level-1 and level-2 quality control:
  - a) Definition of level-2 tunable quality control flags:
    - i) Flags: ringing, scan edge, optical thickness,  $L_{WN}$ , water depth, sun glint, tilt (fixed), ice, turbid Case 2 water, coccolithophores, dust, and  $L_a$ .
    - ii) Masks: clouds.
  - b) Definition of a cloud masking algorithm.
  - c) Definition of level-0 data quality metrics.
3. Persons and tasks identified at the meeting:
 

R. Fraser: Sun glint correction;

R. Frouin: Oxygen ( $O_2$ ), wind direction effects, aerosol models, and African dust (with P. DesChamps);

H. Fukushima: Asian dust (with T. Nakajima);

A. Morel: Vertical stratification, thick dust layer, and high cirrus;

H. Gordon: Implementation, adding any new models, and stratospheric aerosols; and

W. Gregg: Operational aspects.
4. Need more frequent working group meetings.

### 3.9 Round-Robin Calibration

1. Begin working towards a transition from lamps to transfer radiometers.

2. Logs of lamp usage must be maintained and accompany lamps.
3. An approach for field testing of instrument stability must be developed in the near future (this year).
4. The SBRC-GSFC lamp comparison should be repeated and source of original inconsistency identified.
5. Real-time data analysis, cataloging, and archival functions should be emphasized at future round-robin workshops.
6. The Project should publish the results of the round-robin comparisons as volumes of the *SeaWiFS Technical Report Series*.
7. The next round-robin will be held at CHORS during June 14–25 with groups participating in a phased manner rather than all groups working simultaneously.
8. All calibration logs of instruments being used by round-robin participants should be filed with the Project. A format for the logs should be defined by the round-robin working group.
9. A data consistency checklist including tests and criteria for bio-optical data is needed. J. Mueller has volunteered to draft a strawman.
10. A prelaunch solar calibration experiment to be held at SBRC should be considered.
11. International round-robin contacts are R. Doerffer (Europe), M. Kishino (Japan), and O. Kopelevich (Russia).

### 3.10 Field Deployments

1. A common data format should be specified for *in situ* data (see Appendix C).
2. The project should track all field deployments and not just the Project's Marine Optical Characterization Experiment (MOCE) Team (see Table 2 and Appendix D §9).
3. The MODIS Oceans Team optical mooring program should be augmented.

### 3.11 HRPT Policies

1. Since SeaWiFS HRPT stations other than the station at GSFC are not required to archive data they collect, we strongly recommend that options be explored for securing the time series of images that they will be collecting. In the near term it is recommended that the GSFC DAAC act as a central ordering point of other LAC data. This will require the DAAC to work with HQ to assure that the catalog data has been transferred to the DAAC from the Project. For longer term retention, it was suggested that the level-1a data be collected by the DAAC and put into storage at GSFC until they can be made available through the EOSDIS V1.

**Table 2.** Field deployment schedule for SeaWiFS calibration and validation activities.

Location	Contact	Brief Description of Activities	J	F	M	A	M	J	J	A	S	O	N	D
<i>Calendar Year 1991</i>														
Monterey Bay	D. Clark	MOBY test deployment.												
Moss Landing	D. Clark	Submersible <i>in situ</i> radiometer test.												
<i>Calendar Year 1992</i>														
Bermuda	D. Siegel	JGOFS pigments and optical time series.												
Lake Pend Oreille	R. Zaneveld	ONR Optical Closure Experiment.												
Monterey Bay	D. Clark	MOCE-1 instrumentation shake-down.												
Monterey Bay	D. Clark	MOBY at-sea test.												
<i>Calendar Year 1993</i>														
Bermuda	D. Siegel	JGOFS pigments and optical time series.												
S. California Bight	G. Mitchell	CalCoFI bio-optical algorithm validation.												
Baja, Mexico	D. Clark	MOCE-2 final integration of instruments.												
Gulf of Mexico	R. Arnone	Navy optical instruments shake-down.												
Gulf of Mexico	R. Arnone	Navy pigments and algorithm development.												
Equatorial Pacific	S. Matsumura	Pigments and nutrients.												
Lanai, Hawaii	D. Clark	MOBY and deep sea mooring deployment.												
Mediterranean Sea	R. Arnone	Navy validation cruise for SeaWiFS.												
Baja, Mexico	D. Clark	MOCE-3 calibration and validation cruise.												
Western Pacific	A. Morel	OLIPAC† oceanic and atmospheric optics.												
<i>Calendar Year 1994</i>														
Bermuda	D. Siegel	JGOFS pigments and optical time series.												
Lanai, Hawaii	D. Clark	MOBY quarterly refurbishment.												
S. California Bight	G. Mitchell	CalCoFI bio-optical algorithm validation.												
W. Pacific	A. Morel	OLIPAC oceanic and atmospheric optics.												
Hawaii	D. Clark	MOCE-4 initialization and certification.												
European Waters	G. Korotaev	Biogeochemical and optics cruise.												
Hawaii	D. Clark	MOCE-5 calibration and validation cruise.												
Mid-Atlantic Bight	R. Arnone	Navy pigments and algorithm development.												
Baja, Mexico	D. Clark	MOCE-6 calibration and validation cruise.												
Western Pacific	A. Morel	FLUPAC‡ JGOFS pigments and optics.												
Canary Islands	D. Clark	MOCE-7 calibration and validation cruise.												
Arabian Sea	R. Arnone	Navy Case 1 and 2 pigments cruise.												
Arabian Sea	W. Balch	JGOFS mini-process study cruise.												
<i>Calendar Year 1995</i>														
Bermuda	D. Siegel	JGOFS pigments and optical time series.												
Lanai, Hawaii	D. Clark	MOBY quarterly refurbishment.												
Gulf of Mexico	D. Clark	MOCE-8 calibration and validation cruise.												
Baja, California	R. Arnone	Navy regional Case 2 algorithms cruise.												
<i>Calendar Year 1996</i>														
Bermuda	D. Siegel	JGOFS pigments and optical time series.												
Lanai, Hawaii	D. Clark	MOBY quarterly refurbishment.												
Baja, California	R. Arnone	Navy regional Case 2 algorithms cruise.												
Eastern Pacific	D. Clark	MOCE-9 calibration and validation cruise.												

†Oligotrophy in the Pacific (Ocean)

‡(Geochemical) Fluxes in the Pacific (Ocean)

2. The data retention policy of each LAC station should be publicized.

## 4. MEETING SUMMARY

The interactions and information exchanged during the meeting were perceived to be extremely productive. Effective interactions between the Science Team and the Project will be coordinated through an Executive Committee and active continuation of various groups established at the meeting. The subgroups (given in Table 1) are expected to meet at their own schedule prior to and immediately following launch (see Table 3) to address specific topics or resolve action items. The Project agrees to support these meetings and to host the next full meeting of the Science Team which is presently scheduled for 5 months after launch, or March 15, 1994.

**Table 3.** Working groups meeting schedule.

Date	Locale	Group
March 23, 1993	GSFC	SeaWiFS Executive
March 24–26, 1993	GSFC	MODIS Science Team
May 17–18, 1993	GSFC	Atmospheric Correction
May 19–20, 1993	GSFC	Bio-Optical Algorithms
June 14–25, 1993	SDSU	Round-Robin Protocols
March 15, 1994†	GSFC	SeaWiFS Science Team

†Tied to launch (currently Oct. 15) plus 5 months.

Note: April–May 1994 JGOFS Equatorial Pacific Meeting.

The plenary and working group deliberations (Section 3) resulted in 60 specific suggestions concerning the mission. These suggestions were grouped into two categories: recommendations and action items. Although both require consideration, the former are of lesser impact to the Project and acceptance is probably easily accomplished, while the latter represent a potentially significant impact and demand a response where the reasons for acceptance or rejection are clearly delineated. The Project will request written status reports from the person(s) listed in Table 4 as being responsible for completing the recommendation or action item.

Table 4 summarizes and uniquely enumerates the aforementioned recommendations and action items. The recommendations are indicated by the ■ symbol and *italic* numbers), while the action items are indicated by the ● symbol and ***slanted bold*** numbers. Dates given may change pending further review and indicate when written response is required. The Project and the Goddard DAAC will provide their response to each of the entries in Table 4 in a timely fashion.

Although action on some of the recommendations or action items has already been taken, it is unlikely that all of the desired changes can be implemented before launch, due to cost and schedule constraints, but all will be considered carefully. Progress on these latter items will be tracked by the Project, and the Science Team along with

any other concerned individuals or groups will be kept informed of important developments via electronic mail and other means. (Appendix E presents the attendees to the meeting, plus any Science Team members who could not attend, along with their addresses, phone numbers, and e-mail mailboxes.)

### 4.1 Questionnaires

Before and during the meeting, the Project circulated a *SeaWiFS Science Team Meeting Questionnaire*, the results of which are given in Appendix D. The project solicited this information to help plan various aspects of the meeting, in terms of topics to be covered; to establish community needs in specific areas; and to aid the Project in making future decisions where possible Project responsibilities must be weighed against one another. For example, if the Project needs to support a particular software package, but does not have a large enough budget to support all possible operating systems, it's useful for the Project to know the majority of the community uses the UNIX operating system.

Many of the comments in the questionnaire provide important information to the Project. Any hope for global calibration and validation will have to rely on an effective flow of data from the PIs to the project. Fortunately, there is a clear willingness of Team members to supply their *in situ* observations to a central archive. The responses also underscore the need for LAC and HRPT data processing and archiving, distribution of *in situ* data and ancillary data, and subsetting of global data products. Team members are encouraged to read Appendix D, as several contain offers of cruises, data sharing, and are of general interest.

Four survey topics are particularly worthy of a more detailed (but relative) summary:

- a) 57% of the respondents use a UNIX operating system, 26% use DOS, 10% use VMS, and 7% use Mac/OS;
- b) 42% want data on request, 31% will accept it monthly, 13% want it *as available*, 11% want it weekly, and 3% want it quarterly;
- c) 41% will accept data on 8 mm, 29% over the network, 14% on 9-track, 12% on 4 mm, and 4% on CD-ROM; and
- d) Most respondents (approximately 94%) are interested in regional or multi-regional data—not global data.

In computing these percentages, all responses were counted without considering exclusivity. In other words, if a respondent indicated a willingness to accept data on 8 mm and 4 mm tape, both categories were counted. By the same token, someone who uses UNIX and DOS computers was counted once in the UNIX category and once in the DOS category, regardless of the number of computers used in each category.

**Table 4.** A summary of recommendations (■ and *italic* numbers) and action items (● and *slanted bold* numbers) from plenary and science working group sessions.

No.	Item	Responsibility	Status	Due Date
<i>Sensor Acceptance and Testing</i>				
1	■ Review baseline calibration and characterization requirements with test data in digital form.	R. Barnes	Accepted	Completed
2	■ Examine SeaWiFS test results to date.	R. Barnes	Accepted	Completed
3	● Determine adequacy of testing program: a) Radiometer calibration after second TV, and b) Covering diffuser opening in second TV.	R. Kirk and R. Barnes	In Progress	15 March
4	● Form a Calibration Team.	C. McClain	Accepted	Completed
5	■ Change values when recommended by the Calibration Team.	C. McClain and Science Team Members	Accepted	Ongoing
6	● Transfer calibration scale to orbit and recommend solar measurements at SBRC.	C. McClain	In Progress	15 March
7	● Solar irradiance data sources.	C. McClain	Accepted	Completed
<i>Ocean Optics Protocols</i>				
8	● Change saturation radiances in Table 5.	W. Esaias and J. Mueller	In Progress	15 March
9	● Change band 5 to 555 nm and reconsider phycoerythrin in a Summer 1993 revision.	W. Esaias and J. Mueller	In Progress	15 March
10	● Provide recommendations to avoid ship induced turbulence in stratified waters.	J. Mueller	In Progress	15 March
11	● Adopt C8 HPLC techniques and recommend a $C_q$ reverse phase HPLC method for separating monovinyl and divinyl chlorophyll <i>a</i> .	R. Bidigare and W. Esaias	In Progress	15 March
12	● Recommend protocol for revision in a Summer 1993 workshop.	W. Esaias and J. Mueller	Accepted	Completed
<i>Data Products</i>				
13	■ Data over land will be saved at level-1; lakes and large rivers will be saved at level-2.	G. Feldman	Accepted	Completed
14	● Determine the level-3 binned preferred option.	C. McClain and P. Pease	In Progress	15 March
15	● Specify where lossless data compression is useful.	P. Pease	In Progress	1 May
16	● Specify requirements for handling special requests.	R. Kirk	In Progress	15 March
17	● Level-3 standard mapped products at present size.	C. McClain	Accepted	Completed
18	● Revise the method for adding and modifying algorithms (send a copy to the SST, DAAC, and HQ).	W. Esaias and C. Yentsch (see Appen. B)	In Progress	15 March
19	■ Publication of algorithms as a short article in journals, or the <i>SeaWiFS Technical Report Series</i> .	W. Esaias	Accepted	Ongoing
20	● Put plug-in modules for new algorithms in DAAC.	P. Pease	In Progress	1 June
<i>Adding New Products</i>				
21	● Define algorithms, data products, and resources for review by HQ, DAAC, and working groups.	J. Campbell, J. Bishop, H. Gordon, and C. McClain	In Progress	1 April
22	● Define resources and implementation schedule.	P. Pease	In Progress	1 June
23	■ Expect additional products thru life of project.	W. Esaias	Accepted	Ongoing
<i>Field Deployments</i>				
24	■ The project should track all field deployments.	S. Hooker (see Table 2)	Accepted	Ongoing
25	● Specify a common data format for <i>in situ</i> data.	S. Hooker (see Appen. C)	Accepted	Completed
26	■ The MODIS Oceans Team optical mooring program should be augmented.	C. McClain	Accepted	Ongoing
<i>HRPT Policies</i>				
27	● Non-GSFC LAC station archiving.	D. Butler	In Progress	15 March
28	■ The data retention policy of each LAC station should be publicized.	R. Kirk	Accepted	Ongoing

**Table 4 cont.** A summary of recommendations (■ and *italic* numbers) and action items (● and *slanted bold* numbers) from plenary and science working group sessions.

No.	Item	Responsibility	Status	Due Date
<i>Algorithm and Product Validation</i>				
<b>29</b>	● Multiple recommendations for pigment and chlorophyll-like algorithms.	C. McClain	Accepted	1 May
<b>30</b>	● Recommendations for $K(\lambda)$ algorithm.	C. McClain	Accepted	1 May
<b>31</b>	■ Recommendations for historical databases.	C. McClain	Accepted	15 March
<b>32</b>	● Pursue JGOFS distributed database concept.	C. McClain	In Progress	15 March
	● Recommendations for level-3 binning:			
<b>33</b>	a) R. Evans' spatial day definition, and	C. McClain	Accepted	15 March
<b>34</b>	b) J. Campbell's MLE binning statistic.	C. McClain	In Progress	15 March
<i>Data Access and Distribution</i>				
<b>35</b>	● Provide a data pricing policy.	F. Muller-Karger	In Progress	15 March
<b>36</b>	■ Answer the DAAC survey.	Science Team Members	In Progress	ASAP
<b>37</b>	● Software support for IBM RISC stations.	P. Pease	In Progress	1 May
<b>38</b>	● Subsetting of regular products is needed which will require funding from HQ.	P. Pease	In Progress	1 November
<b>39</b>	● Specify compression of browse images if any.	P. Pease	In Progress	1 June
<i>Software Policies and Availability</i>				
<b>40</b>	■ Project's primary responsibility is to produce scientifically credible products.	W. Esaias	Accepted	Completed
<b>41</b>	● Scientific modules to be incorporated to provide level-1 to level-3 processing capability.	C. McClain and G. Feldman	Accepted	1 August
<b>42</b>	● Modules to be distributed as source and executable code by DAAC and SEAPAK group.	C. McClain, G. Feldman, and P. Pease	Accepted	1 August
<b>43</b>	● The DAAC will forward technical questions to the DAAC/SEAPAK support groups.	C. McClain and P. Pease	Accepted	Ongoing
<b>44</b>	■ Software to be distributed by DAAC supported media and transfer mechanisms.	P. Pease	Accepted	Ongoing
<b>45</b>	● Provide software for UNIX (incl. HP) computers.	C. McClain and P. Pease	In Progress	15 March
<b>46</b>	■ Software to be distributed to all requestors.	R. Kirk	In Progress	Ongoing
<b>47</b>	■ All SeaWiFS developed software will be available, but with limited support.	R. Kirk	Accepted	Ongoing
<b>48</b>	■ Up to 6 months software support required after system upgrades to ensure full functionality.	C. McClain	In Progress	Ongoing
<i>Round-Robin Calibrations</i>				
<b>49</b>	■ Transition from lamps to transfer radiometer.	C. McClain	Accepted	15 March
<b>50</b>	■ Maintenance of lamp usage logs.	C. McClain	Accepted	Ongoing
<b>51</b>	■ Develop apparatus and procedures for field testing of instrument stability.	C. McClain	Accepted	15 March
<b>52</b>	● Repeat the SBRC-GSFC lamp comparison.	C. McClain	Accepted	15 March
<b>53</b>	■ Emphasize real-time analysis, cataloging, and archiving.	C. McClain	Accepted	Ongoing
<b>54</b>	■ Publish round-robin results as TMs.	S. Hooker	Accepted	1 May
<b>55</b>	● Next round-robin June 14-25.	C. McClain	Accepted	15 March
<b>56</b>	■ Instrument calibration logs should be filed with the project.	C. McClain	Accepted	Ongoing
<b>57</b>	● A data consistency check list is needed.	C. McClain and J. Mueller	Accepted	1 April
<b>58</b>	● A prelaunch solar calibration at SBRC is needed.	C. McClain	Accepted	15 March
<b>59</b>	■ International contacts need to be maintained.	C. McClain	Accepted	Ongoing
<i>Atmospheric Corrections</i>				
<b>60</b>	■ Hold meeting at GSFC May 17-18.	R. Kirk and H. Gordon	Accepted	15 March

The results of the questionnaire prepared by the DAAC, which covered data distribution in more detail, will be made available separately.

## 4.2 SeaWiFS Executive Committee

A SeaWiFS Executive Committee was established by NASA to help coordinate Science Team activities and to provide rapid advice to the Project and HQ when needed. The members nominated for this committee were: Mark Abbott, Otis Brown, Paul Falkowski, Hajime Fukushima, Eileen Hoffman, André Morel, Jim Yoder, the SeaWiFS Program Scientist (Frank Muller-Karger), and the SeaWiFS Project Scientist (Wayne Esaias). The duties of the executive committee are to be as follows:

1. Assist in the coordination of the activities of the Science Team.
2. Provide quick guidance to the Project on issues and performance when time constraints would not permit consultation with the Science Team.
3. Prepare Recommendations to the Project and NASA HQ as required.
4. Review the real-time support procedures.
5. Assist in defining the transition between SeaWiFS, EOS Color, and MODIS.

The committee will convene as required, perhaps three times annually. Two non-US members are included to directly help coordinate SeaWiFS science activities with planned ocean color missions from the European Space Agency (ESA) and Japan.

## 5. SCIENCE TEAM ABSTRACTS

Science Team members presented a short (10 minute) description of the work each planned as part of the SeaWiFS program. The information presented in this section are the abstracts of the investigators selected through the SeaWiFS NASA Research Announcement (NRA). In general, the abstracts convey much of the information the team member presented at the meeting. The abstracts are presented as *submitted* with very minor modifications to correct typographic or obvious clerical errors. The scope of the investigations may change somewhat as funding levels become more certain.

### 5.1 James Aiken

*SeaWiFS Study of Climate, Ocean Productivity, and Environmental Change (SeaSCOPE)*

The oceans have a fundamental role in the global climate system, through the oceanic carbon cycle, the main long term control of atmospheric CO<sub>2</sub> which is driven by phytoplankton photosynthetic carbon fixation. Historical, sedimentary and ice core records, indicate the intimate involvement of fluctuations in the activity of the oceanic car-

bon cycle and atmospheric concentrations of CO<sub>2</sub> throughout previous glacial/inter-glacial periods of natural climate change. SeaWiFS data will offer truly synoptic measurements of basin scale and global dimensions which are necessary to address these issues. Only SeaWiFS imagery will have the ability to estimate oceanic primary production and the co-related draw-down of atmospheric CO<sub>2</sub> and the exchange between the ocean and the atmosphere of other radiatively active trace gases which combine to determine the strength of the natural greenhouse effect.

SeaWiFS data will provide synoptic large-area, temporally resolved measurements of water colour, which can be related to oceanic biological material and biogeochemical processes and fluxes. This proposal seeks to use SeaWiFS data to address objectives which investigate:

- the role and significance of oceanic biological processes in climate control (including the exchange of CO<sub>2</sub> and important trace gases such as DMS between the ocean and the atmosphere and cloud albedo) for different oceanographic provinces including Antarctica where the ice edge has a special significance;
- ecological and environmental change at the land-sea boundary (phytoplankton blooms and the transport of contaminants via suspended sediments);
- the diffuse attenuation coefficients, mixed layer depths, ocean physical processes, bio-optical signatures as tracers of water motions, spatial heterogeneity, upwelling and frontal dynamics; and
- the role of biology in models of the climate system, which include ocean atmosphere interactions.

The project will be executed under the framework of a number of timely, operational, UK community programmes, co-ordinated by the Natural Environment Research Council (NERC), which will have complementary goals and objectives to those of SeaWiFS. These include: the proposed community project PRIME (Plankton Reactivity in the Marine Environment, appendix 1) which has substantial common ground with the U.S. Global Change Research Project; LOIS (hosted by Plymouth Marine Laboratory, PML, appendix 2) with a focus on environmental change in the coastal zone but including a Shelf Edge Study (SES); OMEX (Ocean Marine Exchange) a European Community project to be hosted by PML; UK-WOCE, particularly the VIVALDI element, including bio-optical and biogeochemical flux measurements (pigments and pCO<sub>2</sub>); British Antarctic Survey (BAS) with several decades of research in Antarctica, an area which is highly susceptible to perturbation (global temperature rise) and where quantitatively significant ice edge phytoplankton blooms occur; the ongoing Continuous Plankton Recorder (CPR) Survey which will acquire bio-optical measurements, seasonally and annually on a monthly schedule from ships of opportunity in the North Atlantic and adjacent shelf sea areas.



The scientific objectives of the project will be addressed by linking: *In situ* measurements, Algorithm development, Image validation, Exploitation of SeaWiFS data using coupled physical-biological models. Measurements. Using research (and merchant) ships towed and moored instrumentation and airborne sensors, we will make measurements of the optical properties of the ocean areas of study and the biogenic constituents which influence water colour, principally phytoplankton, its major and ubiquitous photosynthetic pigment chlorophyll *a*, accessory pigments and DOC. Ancillary measurements will be made of primary production new production, photosynthetic parameters, draw-down of CO<sub>2</sub> and the exchange of trace gases such as DMS.

The implementation of these plans will be supported by the established NERC Satellite Receiving Station (NERC SRC) at the University of Dundee with over 15 years experience of receiving and archiving CZCS and AVHRR data and by a new HRPT station to be established by the British Antarctic Survey (BAS) at Rothera on Adelaide Island (67° 34' S, 68° 7' W) designed and constructed by the NERC SRS Dundee. Satellite image analysis within the UK in support of biological oceanography, has been established for a number of years as evidenced by a substantial list of publications including pioneering work using visible band AVHRR imagery for detection of coccolithophore blooms, and transmissions of processed imagery to ships at sea. This work will continue at the NERC Image Analysis Unit, Plymouth.

## 5.2 Kevin Arrigo

### *A Coupled Ice-Ocean Model of Mesoscale Physical/Biological Interactions in the Southern Ocean*

To investigate the complex interactions between environmental forcing and microalgal distributions in the Southern Ocean and to facilitate interpretation of remotely sensed pigment fields, we propose to develop a dynamic 3-dimensional model of a coupled sea ice/ice edge/open water ecosystem. The model will simulate the depth-dependent physical and biological dynamics within the marginal ice zone (MIZ) and will include components which describe 1) radiative transfer within the sea ice and the water column, 2) water column stratification as it is influenced by surface winds and sea ice meltwater, 3) physicochemical properties of sea ice and the water column (i.e., temperature, salinity, nutrient concentration, etc.), and 4) biological dynamics including the activity of microalgae, grazers, and a simple microbial loop. The availability of remotely sensed data sets will be crucial to model development and performance and includes SeaWiFS pigments, SSM/I sea ice coverage, and ISCCP cloud coverage. When coupled with SeaWiFS ocean color data, this model will be a useful tool for 1) interpretation of observed pigment distributions by predicting depths of the mixed layer and

the chlorophyll *a* maximum, 2) utilizing remotely sensed data to investigate large scale physical and biological interactions between sea ice, the ice edge, and open water, and 3) estimating rates of production in the Southern Ocean and its contribution to total global productivity.

## 5.3 William Balch

### *Towards Improved Estimates of Primary Production and Carbon Turnover During the SeaWiFS Mission*

Our ability to detect algal biomass using the Coastal Zone Color Scanner has improved considerably over the last decade but it is fair to say that our ability to predict primary production from space is still in the exploratory stages. The essence of the problem is that we are trying to derive a rate estimate from a standing stock measurement of chlorophyll. Most of the current primary productivity algorithms are based on the biomass of phytoplankton (as estimated by satellite-derived chlorophyll) and the expected physiological response of phytoplankton to light. I refer to these algorithms as P-I algorithms. Even the best models for calculating integral primary production only account for 12–30% of the variance when using satellite data as input. It is fair to say that we need more information to increase the variance explained by these algorithms. I propose a two-fold approach:

1. Information on the baroclinicity (steepness of the isopycnals) can be derived from the gradient in sea surface temperature (SST) at length scales of hundreds of kilometers. The steeper the isopycnals, the easier it is to mix nitrate into surface waters, which allows more phytoplankton biomass to be sustained. Strong relationships have already been formulated between baroclinicity and integral biomass. I would like to extend the analysis to examine the effects of baroclinicity on integral production. Finally, the length scales at which the baroclinicity/SST gradient relationship applies need to be better defined. Satellite-derived SST fields can provide information on the surface nitrate concentration, the maximum expected growth rate, and the baroclinicity, all of which should help in predicting primary production from satellite.
2. Current satellite-derived estimates of primary production do not incorporate information on the history of the populations in question. Assimilation numbers of phytoplankton (mgC mg<sup>-1</sup> chlorophyll *a*) differ dramatically during bloom formation and decay. It has been difficult to reconcile satellite-derived primary production rates relative to changes in surface pigment observed between consecutive images. This is because changing biomass from one image to the next is due to not only production, but also sinking, advection, diffusion, and grazing. In contrast, production measured in bottles usually excludes grazers, and eliminates sink-

ing, advection and diffusion. I propose to take advantage of this difference. Even though integral primary production estimates are still difficult to make from space, estimates of net surface production are much better. The difference between the net change in surface biomass versus surface production will give a first order estimate of the total loss terms. We will also calculate the turnover time of the phytoplankton carbon in surface waters, something which is of great interest to the JGOFS and GLOBEC programs.

#### 5.4 Robert R. Bidigare

##### *Development of an Optical Model for Estimating Primary Production Rates from SeaWiFS Color Imagery and AVHRR Cloud Climatologies*

A primary goal of the SeaWiFS mission is to improve our understanding of the mean, variance, and control of primary production rates at multiple temporal and spatial scales in order to quantify the importance of phytoplankton carbon fixation in the global carbon cycle. Toward this goal we propose to develop an absorption-based optical model for estimating primary production rates from SeaWiFS color imagery and NOAA GOES AVHRR cloud climatologies. Initially, the model will be used to compute the daily production rates for two locations in the Pacific Ocean centered at 0°, 140°W (site of the U.S. JGOFS Equatorial Pacific Process Study) and 22.75°N, 158°W (site of the U.S. JGOFS Hawaii Ocean Time-Series Program). Once the model has been tested at the local spatial scale, regional production estimates will be computed for the Equatorial Pacific and North Pacific Central Gyre. It is envisioned that regional production rates could be combined to provide basin-scale primary productivity estimates.

As the result of NSF and NOAA sponsored investigations in the Pacific Ocean (e.g., U.S. JGOFS EqPac Study, TOGA COARE, Hawaii Ocean Time-Series Program), we have access to algal physiological data (chlorophyll-specific  $a_{ph}^*$ ,  $I_k$ , and  $\Phi_{max}$ ) and moored optical measurements which allow us to accurately model primary production rates [i.e.,  $P(z,t)$ ] in selected regions of the Pacific Ocean. To date our modeling efforts have been restricted to shipboard and mooring acquired data. We propose to extend these modeling efforts to incorporate satellite imagery for providing daily estimates of integral production,  $\text{mgC m}^{-2} \text{d}^{-1}$ , for the Equatorial Pacific and North Pacific Central Gyre. Input parameters for the satellite-based optical production model include: 1) chlorophyll *a* concentration obtained from SeaWiFS color imagery; 2) the spectral diffuse attenuation coefficient derived from SeaWiFS color imagery; 3) surface solar irradiance obtained from NOAA GOES AVHRR cloud climatologies; and 4) the phytoplankton photophysiological parameters described above.

The accuracy of satellite derived production estimates will in part be dependent upon the quality of chlorophyll

*a* distributions generated from SeaWiFS color imagery. Thus, it is essential that ground truth pigment measurements (i.e., for calibration and validation efforts) are accurate, precise, and representative. Toward this goal, we also propose to provide members of the SeaWiFS Science Team with 1) recommended procedures for sampling, extraction, and analysis of plant pigments (chlorophylls, carotenoids, and phycoerythrin); 2) pure external and internal standards for instrument calibration; and 3) mixed standards and algal extracts for intercalibration purposes.

#### 5.5 James K. Bishop

##### *Production and Analysis of Global Short Wave and Photosynthetically Active Surface Irradiance Fields Using International Satellite Cloud Climatology Project (ISCCP) Data*

Surface solar irradiance is a critical determining factor of marine (and terrestrial) productivity. It is the driving force for photosynthesis and it is important in governing the stability of the water column (hence stability in the light field experienced by phytoplankton). This proposal will support SeaWiFS team efforts by: 1) Providing global surface solar irradiance fields at 280 km resolution on a 3 hr/daily/monthly basis computed from ISCCP data using the Bishop and Rossow (1991) algorithm (and updates of that algorithm). 2) We propose limited production of surface irradiance fields at 30 km resolution using Rossow's CX data set to meet the needs of regional investigations of pigment-irradiance systematics in ocean regions where sharp lateral gradients in pigments or other environmental variables are found. The proposed work is in collaboration with scientists at NASA's Goddard Space Flight Center/Goddard Institute for Space Studies (GISS) in New York.

We propose also to work with SeaWiFS data pertaining to aerosol optical thickness so as to improve our own estimates of surface solar irradiance. We will also work with SeaWiFS data and SeaWiFS team members to develop parameterizations for particulate carbon flux. This work draws on our experience gained from independently funded shipboard investigations of particle dynamics of the upper kilometer as part of JGOFS. Such experience is necessary to establish the links between environmental forcing and particulate carbon export from the euphotic zone to the deep sea.

#### 5.6 Giancarlo Carrada

##### *Space-Time Variability of Plankton Growth Due to Mesoscale Structures in the Mediterranean Sea: A Comprehensive Study by Space Remote Sensing*

This project represents a cooperative international study using ocean color observations of the Mediterranean Sea to improve existing models evaluating primary production from integrated satellite data. It addresses some basic

questions aimed at improving our knowledge of plankton dynamics and at exploring the information contained in the remote sensing data relevant to this research framework.

The attempt is to evaluate the role in that dynamics played respectively by ecophysiological parameters and environmental forcings.

Among the ecophysiological ones, the major parameters are considered to be underwater irradiance spectra and action spectra of photosynthesis in their geographical, vertical and temporal variability. On the other hand, effects of environmental forcings can be summarized as a whole in the surface variability induced by wind, dynamical and thermohaline forcing.

Surface dynamics, both physical and biological, detected from salinity, temperature, chlorophyll and velocity, can be classified according to a reduced set of patterns, which can also be correlated with vertical processes, which affect the penetration and the spectral characteristics of the light. This in turn affects, even if on different time scales, consumption and losses.

Main goals of the proposed research consist therefore basically in: assessment of the dependence of optical profiles on pigment composition of plankton organisms and viceversa; evaluation of the correlation degree between surface and vertical dynamics in the observed systems, so as to anticipate the shaping of biomass profiles from surface dynamics; estimation of the typical response time of plankton communities compared with environmental change time scales.

An interdisciplinary approach is the primary characteristic of the present proposal. A big effort has been accomplished to assemble scientists whose activity contribute to produce the comprehensive data set necessary for the purpose of the proposed research.

We intend to carry out three oceanographic cruises per year in which hydrological, currentmetrical, biooptical and strictly biological data will be collected in coincidence with SeaWiFS passages and with the utilization of airborne color and shipborne Lidar sensors. These data, together with the full coverage of SeaWiFS passages, will form the basis for an activity of outlining, developing and validating a bio-physical model which describe the dynamics of primary production along the water column in an environment characterized by a strong mesoscale variability.

## 5.7 Glenn F. Cota

### *Collaborative Research on Remote Sensing of Ocean Color in the High Arctic*

Phytoplankton productivity in the high Arctic can be comparable with the most productive areas of the world's oceans and may play an important role in the carbon cycle (Smith et al. 1991). Our primary objective is to assess the utility of ocean color as an indicator for the biomass and primary production of phytoplankton at high latitudes

(above the Arctic circle). The influence of phytoplankton on biogeochemical cycles of carbon and nitrogen and the variability of apparent bio-optical properties will be determined for SeaWiFS surface truth. Our goal is to acquire sufficient *in situ* bio-optical and biogeochemical data to develop and validate local and regional algorithms. Polar waters may serve as model systems because of the strong biophysical coupling (e.g., melt water stratification and ice edge blooms), but they are remote, inaccessible and inhospitable. Along with other types of remotely sensed data, ocean color, if properly validated, should allow us to survey polar environments routinely. We will investigate open water and marginal ice edge regions where sensor performance (snow/ice/cloud glare or *ringing*, high levels of dissolved materials) may require local and regional algorithms.

Concurrent data sets will be gathered on incident spectral irradiance  $E_d(0^-, \theta)$ , downwelling spectral irradiance  $E_d(z, \theta)$ , upwelling spectral radiance  $L_u(z, \theta)$ , sea and sky state photographs, wind speed, phytoplankton pigments (HPLC and fluorometric), total suspended matter (TSM), particulate organic carbon (POC) and nitrogen (PON), dissolved colored organic material (DCOM), dissolved organic carbon (DOC), *in situ* fluorescence, red beam attenuation, inorganic nutrients, hydrographic variables,  $^{15}\text{N}$ -nitrogen uptake (nitrate and ammonium) for new production and total  $^{14}\text{C}$ -primary production. Field programs will be conducted in Baffin Bay and in the Northwest Passage. Knowledge of the productivity of the Arctic is important for modeling the global carbon cycle, predicting the effects of global climate change, and modeling polar food webs. The ability of the Arctic Ocean to act as a carbon sink depends on *in situ* productivity on the shelves of marginal seas, nutrient supply and imported carbon (Walsh 1989, Anderson et al. 1990). Satellite remote sensing is the only practical means to monitor polar regions.

The US currently does not operate a high latitude field station nor do we have vessels dedicated to oceanographic research in the Arctic. Hence, cruises in the high Arctic are rare, and cooperation with other nations is often mandatory. In this case the Canadians are willing to provide ship time and certain equipment and facilities at a nominal cost (well below the cost of ship time) and to collaborate directly at no additional cost to NASA.

## 5.8 Roland Doerffer

### *SeaWiFS Application to Water Type Case II: Development of Algorithms and Investigation of Biogeochemical Processes in the Coastal Zones*

A major part of the European coastal zones and enclosed basins such as the North Sea and Baltic Sea belong to Case II water. These areas require special algorithms and *in situ* truth procedures in order to separate the contribution by the different water constituents to the water leaving radiance spectrum. At the GKSS Research Centre an inverse modelling technique has been developed to

retrieve the concentration of suspended matter, gelbstoff and phytoplankton pigment as well as the aerosol path radiance from remotely sensed radiance spectra. This procedure has been successfully tested with CZCS and aircraft spectrometer data.

It will be adapted and further developed for SeaWiFS. The data of SeaWiFS will be used within the framework of the IGBP program LOICZ (Land Ocean Interaction in the Coastal Zone). Main areas of research will be the North and Baltic Sea. Questions for the application of the data are: temporal and spatial development of plankton blooms including exceptional blooms, primary production of Case II water including the determination of the depth of the euphotic zone and the photosynthetic available radiation PAR (ISCCP data), transport of dissolved organic material from the rivers into the sea, erosion, transport and sedimentation of suspended matter. We intend to test and apply the procedures also for other areas, where a separation of different substances is required (e.g., Yellow Sea). A further task will be the analysis of SeaWiFS data with respect to aerosols and thin cirrus clouds including contrails. They are important because of their masking effect for water surfaces, but also because of their impact on the atmospheric radiation and energy budget.

The research program will include optical *in situ* measurements with a new developed multicollector underwater spectrometer and aerial surveys with an airborne high resolution spectrometer and an imaging spectrometer (RO-SIS). Furthermore data of NOAA AVHRR, METEOSAT and Thematic Mapper will be included in the research program.

## 5.9 Paul G. Falkowski

### *Integrating Primary Production Measurements into Satellite Maps of Ocean Color*

We propose to integrate a consensus primary production model into SeaWiFS ocean color database. To meet this goal, we suggest that the production models be parameterized with inherent physiological state variables, such as optical cross section and quantum efficiency of photosynthesis, that will be independently determined from *in situ* measurements. These parameters will be applied to the whole range of physiological conditions in the world ocean. This type of parameterization will lead to greater objectivity in assessing sources of variance in model results. Model documentation and code, as well as *in situ* data, would be resident in a NASA database (which we will help to establish) and would be accessible to all interested investigators. Model improvement and criteria would evolve from an intercomparison exercise in which a consensus data set would be available to individual investigators for analysis. The data would be iteratively decimated and individual model sensitivity would be objectively assessed. We propose that by developing a traceable, documented, investigator-independent, and uniform (even if imperfect)

production model to ocean color data, iterative model improvements based upon increased knowledge and understanding can be readily implemented. Such iterative consensus model development will allow oceanographers in the 21st century to deduce true changes in primary production in the oceans from model and source data variability.

## 5.10 Robert J. Frouin

### *Inversion Schemes to Retrieve Atmospheric and Oceanic Parameters from SeaWiFS Data*

We propose 1) to study, using theoretical simulations and observations, atmospheric effects on SeaWiFS radiance, including their variability, evaluate the scheme proposed to correct these effects, define improvements or adjustments, and verify, during the post-launch phase of the SeaStar/SeaWiFS mission, the quality of the atmospheric corrections, and 2) to develop, test, and validate new inversion schemes to retrieve atmospheric and oceanic parameters.

The first objective will focus on the effects of aerosol-molecule, foam-molecule, and glitter-molecule coupling, wavelength varying aerosol optical properties, wind direction, oxygen absorption in the SeaWiFS 765nm band, small clouds within the field-of-view, bidirectionality of the water-leaving radiance, and spatial heterogeneity of the ocean and atmosphere.

The second objective will include the development of two inversion schemes, fundamentally different from the traditional, two-step scheme. We shall not seek to retrieve first wavelength-dependent parameters such as water-leaving radiance or aerosol optical thickness and, then, geophysical parameters (e.g., aerosol loading and type, phytoplankton pigment concentration), but geophysical parameters directly and simultaneously, thus avoiding the extra step.

In the first inversion scheme, the atmospheric and oceanic parameters to retrieve will be expressed as linear combinations of SeaWiFS radiances or, equivalently, reflectances, and the coefficients will be determined by minimizing the influence of noise in the data and the interdependence of the estimators. The proposed scheme, thus, does not extract water-leaving radiance in order to estimate oceanic parameters. The coefficients of the linear combinations, which are pixel-specific, only depend upon the sensitivity of the top-of-atmosphere radiance. Since the problem is non linear, however, the scheme is iterative in nature, and requires a first guess of the geophysical parameters. This first guess will be obtained by comparing the SeaWiFS radiances to values pre-calculated for a wide range of atmospheric and oceanic conditions.

In the second inversion scheme, a feedforward neural-like network composed of several layers of intermediate nodes will be educated, using back propagation, to associate SeaWiFS radiances (input vector) to geophysical

parameters (output vector). A training data set, obtained from radiative transfer calculations, will be used in the supervised learning process. The resulting mapping is expected to associate correctly input and output vectors when the input vector is outside the training set.

Two aircraft data sets acquired during the MEDIMAR and RACER campaigns with the airborne version of the Polarization and Directionality of the Earth's Reflectance (POLDER) instrument will be used to study the atmospheric effects and validate the inversion schemes prior to the launch of SeaStar. The study of atmospheric effects before launch will also be performed using a specific atmospheric optics instrumentation that will measure sun and sky radiances (including aureole) in spectral bands as close as possible to those of SeaWiFS. This instrumentation will be installed at appropriate ground sites. After launch the instrumentation will be used systematically to verify the atmospheric corrections. It will be modified to operate properly at sea during SeaWiFS calibration/validation cruises or cruises of opportunity.

The investigation will provide an assessment of the atmospheric effects on the SeaWiFS radiances and will conclude on the ability of traditional schemes to correct these effects. It will also conclude on the adequacy of new inversion schemes to retrieve oceanic and atmospheric parameters from SeaWiFS radiances. Maintaining a check-of-quality of the SeaWiFS data and products during the post-launch phase will be important to the success of the SeaStar/SeaWiFS mission; our atmospheric optics instrumentation will address this issue and provide, on a regular basis, a verification of the atmospheric corrections. By contributing to interpret quantitatively ocean color measurements from space in terms of parameters governing primary production, the investigation is relevant to international global change programs such as the International Geosphere-Biosphere Program and its Joint Global Ocean Flux Study, which have identified understanding the role of marine primary production in the global carbon cycle as a major objective.

### 5.11 Hajime Fukushima

#### *Study of Asian Dust Aerosol: Correction of Optical Effects and Estimation of Flux*

The transport of Asian dust particles (KOSA) through the atmosphere to the Northwest Pacific is the most intensive one of this kind on the globe and is important in terms of geochemical cycle. The dust particles are also known to affect atmospheric correction process of satellite ocean color data, resulting in erroneous estimation of phytoplankton pigment concentration which, in turn, affects the proper evaluation of primary production in the area.

The objectives of the proposed study are 1) to contribute on SeaWiFS atmospheric correction algorithm adjusting to the special aerosol type in this region and 2)

to investigate feasible method to estimate the flux of mineral particles from the satellite data, by comparison with ground level sampling of dust particles. Since the latter part relies on a well-established atmospheric correction algorithm we will mostly work for the former objective during the first 2–3 years.

Regarding the atmospheric correction, we have already developed and are testing a prototype algorithm based on the standard Gordon's scheme. It assumes absorption of Asian dust particles and calculates spectral aerosol optical thickness iteratively in a pixel-by-pixel basis. Although currently we need to give the spectral absorption by experience, we plan to refine the scheme or refine the procedure determining the modeled aerosol optical properties, with the aid of well-calibrated and well-organized *in situ* data set. From this point, we also plan to conduct continuous ground measurement of sky radiance on a remote island to obtain spectral solar aureole intensity distribution together with other pertinent properties. From the obtained quantities and by comparing them with upwelling radiation received by the satellite sensor, we will get aerosol optical thickness and single scattering albedo as well as degree of non-sphericity of aerosol. Supported by these activities and in collaboration with other SeaWiFS team/project scientists, we consider we can refine and validate the scheme so that it can be implemented into the SeaWiFS/OCTS atmospheric correction algorithm during the planned research period.

### 5.12 Carlos A. E. Garcia

#### *Optical/Biological/Physical Measurements in the South Atlantic Ocean for Development of Basin and Local Bio-optical Algorithms*

This research proposal seeks to provide *in situ* optical/biological/physical observation data in the South Atlantic Ocean for SeaWiFS products verification and development of bio-optical algorithms. The data set will be collected during the British and Brazilian surveys in contribution to the World Ocean Circulation Experiment (WOCE) in the South Atlantic Ocean.

The UK contribution to the WOCE One-time Hydrographic Survey includes the leg A23 along the 35° W meridian, from January to March 1994, commencing as far as possible into the Weddell Sea and proceeding northwards across the Antarctic Circumpolar Current (ACC), and at about 32° S turning northwest towards the Brazilian coast. A comprehensive suite of physical (temperature, salinity, and current profiles), optical (spectral underwater irradiances, spectral reflectances, and beam attenuation), and biogeochemical (phytoplankton pigment, fluorescence profiles, suspended matter and continuous underway chlorophyll *a* fluorescence) measurements obtained during the survey will provide the basis for SeaWiFS product verification and development of biogeographical bio-optical algorithms. The one-time survey crosses several water types

and fronts (e.g., Polar and Subtropical Fronts), therefore a great variability of phytoplankton abundance is expected.

Four oceanographic surveys will be undertaken in the Brazilian southern coastal waters (30–34° S) from 1993 to 1995. In this region, phytoplankton abundance is strongly affected by nutrient input from the Lagoa dos Patos and Rio del la Plata estuarine systems, and the presence/absence of subantarctic waters on the continental shelf waters. Primary production rates in the area were shown to vary from 45–177 mgC m<sup>-2</sup> h<sup>-1</sup> with a maximum in spring time (Ciotti 1990). Because the cruises are planned for calculating seasonal changes in the Brazil Current fluxes at 30° S, changes in optical properties (spectral upwelling radiances, downwelling/upwelling irradiances and PAR irradiance profiles) associated with water contents at each season of the year can also be investigated. In this Case II waters, a broader analysis of water content will be made in addition to the measurements in the Southern Ocean. The photo-physiological responses of near surface phytoplankton supplemented by *in vitro* water column primary production measurements will also be investigated to develop a regional model for estimating primary productivity by remote sensing.

The objectives of this proposal are straightforward: to supply bio-optical shipboard data from the South Atlantic Ocean to the NASA Science Team, to initiate an important relationship between several oceanographic institutions, and, equally important, to establish an ocean colour group in South America.

### 5.13 David M. Glover

#### *A Coupled Biological-Physical Model for Studying Annual and Inter-annual Variability in SeaWiFS Ocean Color Data*

We propose to develop a three-dimensional, global scale, coupled biological-physical model for the ocean. SeaWiFS ocean color data will be used in diagnostic fashion to improve the formulation of the biological dynamics in the model and to validate model behavior on large temporal (monthly to interannual) and spatial scales (greater than eddy resolution to global). The correspondence between the model results and the SeaWiFS data will be tested using appropriate time averages for the mean and variance fields (first and second moments). Emphasis will be placed on replicating in a statistical sense the seasonal variability and large-scale patterns in the SeaWiFS ocean color data. Model sensitivity analysis will be employed during model development and will provide recommendations for future field and process studies. The results of the sensitivity analysis will also be used to explore the *error structure* of the coupled model, laying the groundwork for ocean color data assimilation. Coupled model simulations will be examined to clarify the roles of vertical mixing, upwelling, and horizontal nutrient transport in ocean productivity.

We will also investigate, using the coupled model, the response of the biological-physical system to climatic changes in atmospheric forcing and/or ocean circulation. The development of better coupled biological-physical models is essential if we are to fulfill the overall scientific goals of the SeaWiFS project and understand the role of oceanic primary production in the global carbon cycle.

### 5.14 David Halpern

#### *Seasonal-to-Interannual Variations of SeaWiFS-Derived Phytoplankton Pigment Concentration Along the Equator and Relationships to Physical Oceanographic Processes*

One source of oceanic consumption of atmospheric carbon dioxide is phytoplankton production, especially in the equatorial Pacific. An unusual blend of upwelling and shear mixing, which uplifts nitrate into the euphotic zone, occurs at the equator. Satellite-borne ocean color measuring instrumentation will provide extensive data sets of the global surface-layer phytoplankton pigment concentration beginning in August 1993 when SeaWiFS is scheduled for launch. Research towards understanding the physical oceanographic influences on the annual and interannual variations of the SeaWiFS-derived phytoplankton pigment concentration along the equator is described in the proposal. Monthly longitudinal profiles of phytoplankton biomass will be assembled for each equatorial ocean. The relationship of the annual cycle, interannual variations, and submonthly fluctuations will be related to the physical oceanographic environment, such as sea surface temperature, mixed layer depth, wind mixing, and upwelling intensity. An answer to the question, "To what extent does upwelling control phytoplankton abundances along the equator?" will be sought with studies of the upward nitrate flux at the bottom of the euphotic layer. Sub-surface oceanographic variables, such as temperature and vertical motion, are routinely produced by the NOAA National Meteorological Center (NMC) operational hindcast-analysis system. Mixed layer depth and nitrate flux will be computed from NMC data. Sea surface temperature will be estimated from NOAA AVHRR measurements. Wind mixing will be estimated from SSMI and the ERS-1 AMI data.

### 5.15 Eileen Hofmann

#### *Assimilation of Ocean Color Measurements into Physical-Biological Models*

This proposal outlines a study that is designed to provide a framework for using ocean color measurements with physical-biological models. The two primary objectives of this research are: to develop approaches and techniques for assimilation of ocean color data into physical-biological models and to demonstrate the feasibility of using patterns in ocean color images to specify characteristic vertical

chlorophyll profiles for use in models to estimate primary production. Our initial efforts will be focused at regional scales, specifically the southeastern U.S. continental shelf. However, once developed, the ideas and approaches that will come from this study can be extended to larger (i.e., basin) scales. The proposed research is relevant to three of the five research goals and objectives stated in the NASA Research Announcement for SeaWiFS.

### 5.16 Richard Iverson

#### *Marine Phytoplankton Annual Carbon Production, New Nitrogen Production, and Export Production Calculated from CZCS and SeaWiFS $C_{\text{sat}}$ Data*

Central scientific objectives of SeaWiFS data analysis are to develop methods to estimate new and total primary production on local, regional and ocean basin length scales from satellite chlorophyll *a* estimates and to apply those methods to SeaWiFS data. Two approaches currently exist for estimating primary productivity using remotely sensed data. An empirical approach uses regression analysis to relate productivity to chlorophyll *a* ( $C_{\text{sat}}$ ) determined from satellite imagery (Platt and Sathyendranath 1988; Balch et al. 1992). When both algorithm types were parameterized using composite daily productivity data sets and compared with field data,  $R^2$  values were low (Balch et al. 1989 and 1992).

Both model types are parameterized using  $^{14}\text{C}$  productivity data. The standard  $^{14}\text{C}$  method has bias associated with contamination problems (Fitzwater et al. 1982; Chavez and Barber 1987) that can now be corrected to values obtained with clean- $^{14}\text{C}$  methods (Iverson, Appendix I). A new empirical equation parameterization uses clean-corrected total carbon production ( $P_{TC}$ ) data that are linearly related to annual mean  $C_{\text{sat}}$  with  $R^2 = 0.97$ . The new  $P_{TC}$ - $C_{\text{sat}}$  empirical equation can be used to calculate total production on ocean region and ocean basin length scales. For example, North Atlantic primary production of  $7.9 \text{ Gt C yr}^{-1}$ , determined using the empirical equation, was within the limits of  $9 \pm 3 \text{ Gt C yr}^{-1}$  estimated by Platt et al. (1991) using a semianalytical model applied to seasonally-averaged 1979 CZCS  $C_{\text{sat}}$  data (Iverson and Esaias, Appendix II). Assuming the empirical equation applies to all ocean regions, global ocean primary production increased from  $27 \text{ Gt C yr}^{-1}$  estimated by Berger et al. (1987), to  $57 \text{ Gt C yr}^{-1}$  estimated with the new empirical equation and the global CZCS data set (Iverson and Esaias, Appendix II).

The research proposed here would (1) improve the  $P_{TC}$ - $C_{\text{sat}}$  empirical equation using data to be collected at JGOFS BATS and HOTS sites and available from NODOC in the Balch et al. (1992) data compilation. The equation would be initially tested (2) for different ocean regions by comparing  $P_{TC}$ , calculated using the global CZCS annual average  $C_{\text{sat}}$  data set, with  $P_{TC}$  from the corrected global

standard  $^{14}\text{C}$  data set. Later,  $P_{TC}$  calculated from SeaWiFS  $C_{\text{sat}}$  data will be tested (3) against *clean*  $P_{TC}$  estimates from JGOFS Indian Ocean data. While it will take years or decades to obtain enough data to parameterize semianalytical models for most ocean basins, this research will (4) immediately determine if detectable interannual changes exist in ocean basin-scale  $P_{TC}$  using CZCS data. The same objective will be achieved (5) in later years using SeaWiFS  $C_{\text{sat}}$  data sets, that will have significantly less spatial and temporal sampling bias than CZCS data. Finally (6), equations that relate new nitrogen production (Iverson, 1990) and export production (Iverson, Appendix I) to  $P_{TC}$  will be applied to determine the magnitudes and interannual changes in those variables within different ocean regions and basins using SeaWiFS data.

### 5.17 Daniel Kamykowski

#### *The Influence of Vertical Mixing on the SeaWiFS Algorithms*

Algorithms that relate the signals received by a satellite ocean color scanner (SeaWiFS) to phytoplankton biomass and production (total and new) presently assume a physically static water column. The literature, however, clearly demonstrates that vertical mixing can influence these algorithms. We propose to explore how vertical mixing in natural water columns influences the diffuse reflectance as related to phytoplankton biomass, the photosynthetic state of phytoplankton, and the nitrate flux. Our approach includes field, laboratory and biophysical modeling components focused on developing weightings that can be applied to ocean color algorithms to account for the effect of vertical mixing. We also propose to explore how well vertical mixing in support of the phytoplankton perspective can be estimated from information derived from other satellite sensors (i.e., AVHRR, scatterometer, SAR) both separately and as supplemented by moorings and analyses of historical data collections. Our proposed consideration of vertical mixing can contribute to better estimates of carbon and nitrogen flux in the upper ocean and to the improved precision of satellite ocean color algorithms.

### 5.18 Dale A. Kiefer

#### *Analysis of Photosynthetic Rate and Bio-optical Components from Ocean Color Imagery*

Our research in bio-optical modeling indicates that the value of SeaWiFS imagery can be greatly enhanced by incorporating into the analysis of ocean color both mathematical models of the growth and physiological adaptation of phytoplankton and information on the absorption and backscattering properties of microparticles that are known to contribute to variability in the spectral reflectance at the sea surface. As members of the SeaWiFS Team, we



would continue to develop algorithms that would be applied to the calculation of the concentration and photosynthetic rate of phytoplankton within the water column. These algorithms are distinctly different from those proposed by other workers (e.g., Platt and Sathyendranath 1988, Platt et al. 1991, Morel 1991, Morel 1991) because they are more mechanistic and include a description of the variability in the cellular chlorophyll *a* concentration.

We propose to test and tune our phenomenological productivity model by comparing predictions of phytoplankton concentration and photosynthetic rate obtained from both CZCS and SeaWiFS imagery with measurements at weather stations and moorings such as those presently operating at the Bermuda JGOFS time series. The model will also be validated by measuring rates of growth and light absorption by cultures of phytoplankton grown continuously over a range of temperatures, light intensities, photoperiods, and nutrient concentrations.

We also propose to develop a spectral reflectance model, which will provide a better understanding of the components in the microplanktonic community that contribute to changes in ocean color. We have acquired a large database on the spectral absorption coefficients of marine particles and have developed several methods for separating these spectra into at least two components: phytoplankton and "detritus." We wish to expand this database with measurements made during the SeaWiFS validation cruises and subject the database to an analysis specific to the wavelengths of the SeaWiFS sensors. We have also begun to develop a catalogue of the absorption, total scattering, and backscattering cross-sections of diverse microparticles, including procaryotic heterotrophic and photosynthetic organisms, phytoplankton, flagellates, ciliates and viruses. This information will be incorporated into our development of the reflectance model.

We propose to apply our reflectance model to an analysis of the spectral reflectance measured during the CZCS and SeaWiFS validation cruises. We hope to retrieve at least three components, including the absorption coefficient of phytoplankton and detritus and the backscattering coefficient of suspended particles. If flow cytometric or electronic particle sizing information is gathered during the SeaWiFS validation cruises, we also propose to invert our model by reconstructing the reflectance spectrum from knowledge of the composition and size distribution of suspended particles.

## 5.19 Motoaki Kishino

### *Evaluation of Temporal and Spatial Variabilities of Phytoplankton Pigment and Primary Production in the Japan Sea*

We will study temporal and spatial variabilities of phytoplankton pigment and primary production in the Japan Sea by a moored optical buoy system and SeaWiFS ocean

color data. This study is composed of three major efforts: development of in-water pigment and primary production algorithms, analysis of SeaWiFS data combined with the moored optical buoy data, and development of a vertically one-dimensional physical-biological-optical model. The combination of these three efforts will contribute not only to the regional biological oceanography but also to the general understanding of the variability of primary production and biogeochemistry of the ocean and to the methodology to use satellite and moored buoy data.

Moored optical buoy system was developed by National Development Agency of Japan (NASDA) for evaluation of the algorithms for Ocean Color and Temperature Sensor (OCTS) on Advanced Earth Observing Satellite (ADEOS), which will be launched on 1996. This buoy system will be deployed on the Yamato Bank in the Japan Sea from 1993. Data of spectral upward radiance, downward irradiance, pigment fluorescence, and other physical and atmospheric parameters will be transmitted to the ground station by the weather satellite (GMS) near real time. We will use these information for the evaluation and interpretation of SeaWiFS data. Spectral measurements of optical characteristics of water around Japan will be also conducted to develop pigment and primary production algorithms which are suitable for this area and for the new ocean color sensors. These algorithms will be used to study the temporal and spatial variabilities of phytoplankton pigment and primary production in the Japan Sea. Furthermore, a vertically one-dimensional physical-biological-optical model will be developed and will be compared and coupled to the buoy and satellite data to study the variabilities.

## 5.20 Oleg V. Kopelevich

### *SeaWiFS Algorithms Development and Applications: Applications of SeaWiFS Data*

#### *Objectives:*

1) Development of models and algorithms using the SeaWiFS data for the atmospheric correction and the derivation of optical and biological properties of the upper ocean taking into account the vertical stratification; 2) Validation of developed algorithms carrying out the subsatellite ocean experiments; 3) Use of the SeaWiFS data for the assessment of the global ocean primary production, the carbon flux and of their annual cycle as well for studying the physical and biological processes in regional mesoscale ecosystems.

#### *Approaches:*

1) We intend to improve algorithm of atmospheric correction trying to decline the assumption about a negligible quantity of the water-leaving radiance in the red spectral region and to take into account the case of small foam coverage of sea surface. We also suppose to raise an accuracy



of the extrapolation of the aerosol spectral optical thickness to the blue region using available statistical data of measurements in different ocean areas. Using the sea water optical properties model we hope to develop the general bio-optical algorithm which parameters will be adapted to different ocean condition including the Cases 1 and 2 water. The model of the vertical distribution is supposed to calculate the optical and biological characteristics in the upper ocean to 200m by the ones in the surface layer. For assessment of the primary production we intend to use as empirical algorithms as semi-analytical models. We will try to raise an accuracy of an estimation of maximum photosynthesis basing on oceanological analysis of different situations.

2) We intend to carry out the validation of various algorithms in the all-round sub-satellite ocean experiments. Our Institute has got research vessels which allow to have 60–75 scientists onboard and to carry out all necessary measurements simultaneously. We have instrumental sets providing almost all observations requirements and new devices are planned to develop. We would like to arrange cooperative cruises for the SeaWiFS Calibration and Validation with participation of U.S. scientists.

3) The global ocean primary production, the carbon flux are planned to assess using jointly SeaWiFS and available *in situ* measurements data sets. We also intend to use SeaWiFS data for research of spatial and temporary variability of optical and biological characteristics in coastal upwelling and frontal zones in some areas.

## 5.21 Gennady K. Korotaev

### *SeaWiFS Algorithms Development and Applications to Black Sea Research*

As a result of researches of many years large archives of *in situ* data have been collected in MHI. Main features of spatial and temporal variability of processes in the Black Sea have been outlined. Nevertheless a number of essential details remain not cleared up. Use of data obtained from new enhanced satellite sensors may prove very helpful for detecting sources of sea pollution and mechanisms of its spreading, annual heating and cooling of water, phytoplankton blooming, etc. One of the most significant problems is constant deterioration of ecological state of the Black Sea basin.

The aim of these research works in general consists in development a set of complex optical, hydrophysical and hydrobiological models to enable the use of satellite data for systematic and comprehensive observations and predictions of the state of Black Sea basin.

Quantitative methods of interpretation of SeaWiFS data intended for determining optical and biological characteristics of sea water must be constructed on the basis of complete optical model of “atmosphere-sea” system. At present such model exists for open ocean areas, but

for Black Sea basin the problem is more complicated due to large variety of independent variable parameters of sea water and atmosphere [phytoplankton pigment concentration, dissolved organic material (gelbstoff or yellow substance), various fractions of inorganic suspended materials, etc.]. Processing algorithms and appropriate optical models must be validated and defined more precisely taking into account particular optical properties of the atmosphere and sea water for various regions and conditions.

The main approach to solving the stated problems consists in the use of SeaWiFS data in conjunction with *in situ* data sets. More substantial results would be obtained in case not only comparisons but if the SeaWiFS data would be used for, first, optical models and algorithms adjustment and, second, investigations of diverse processes in the sea.

MHI has several research ships enabling it to carry out field programs in any region of the Ocean. The ships are equipped with a number of hydrological, optical, and other scientific instruments. MHI plans to perform 2–3 field expeditions (about 1 month each) in the Black Sea in a year.

A wide range of theoretical study is performed in MHI aimed at implementation of models of hydrodynamical processes for various scales and regions. The latest models are intended to account for biological processes.

MHI plans to provide the same works within the framework of international project “Priroda.” This project will be realized in 1993–1995 on the base of Russian orbital station “MIR.” The remote sensing instruments will include scanning spectrometer of visible band MOS, constructed in Germany. Experiments with SeaWiFS and MOS can provide reciprocal complement.

## 5.22 J. Ruben Lara-Lara

### *Characterization of the Bio-optical Properties of the Gulf of California*

Our proposal has two main goals: a) the characterization of bio-optical properties in an extensive manner in the Pacific coastal waters off Baja California, and the Gulf of California; and b) intensive study in the Guaymas Basin of the Gulf of California. In this brief summary of our proposal, I describe mainly our intensive study in the central part of the gulf. We propose to obtain continuous basin-scale estimates of primary productivity by combining SeaWiFS time series of surface pigment concentration in the Gulf of California with ship-based characterization of local bio-optical provinces in terms of vertical pigment and irradiance attenuation structure, direct measurements of photosynthesis vs. irradiance parameters and *in situ* productivity, and continuous estimates of pigment concentration and primary productivity from moored natural fluorometers. Our goal is to establish quantitative relationships between the rates of primary productivity and deposition of organic matter into the anoxic varved sediments on the

continental slope of the Gulf of California near Guaymas, Mexico.

The El Niño events signal is well preserved in the gulf varved sediments, therefore this place offers a unique opportunity to study the coupling between the pelagic processes and the fluxes of carbon to the benthos. We will undertake this research in collaboration with the SeaWiFS research proposed by Drs. James Mueller, R. Zaneveld, J. Svekovsky and Dennis Clark.

### 5.23 Marlon Lewis

#### *Satellite (SeaWiFS) Observations of Variability in the Penetration of Visible Light in the Oceans: Biophysical Bases and Physical Consequences*

Prediction of the optical properties of the upper ocean is of central importance in oceanography. The properties regulate the penetration of visible radiation in the sea which has important ramifications for both physical and biological oceanographic processes. In particular, variations in the divergence of visible radiation have a first order influence on upper ocean heat storage, and the development of thermal structure and dynamics on scales ranging from the diurnal to the climatological.

We plan to use SeaWiFS data, along with drifting optical buoy data, and other ancillary data sets, to carry out an investigation into the role of variations in optical properties on upper ocean thermal dynamics on synoptic scales. The SeaWiFS ocean color satellite is particularly well suited to this study; satellite-derived measurements of water-leaving radiances can be used to generate direct estimates of the spectral attenuation coefficient which governs the penetration of light in the sea. These data will be assimilated in both analytical and numerical models of upper ocean thermal response focusing on three time scales. First, the diurnal response of the upper ocean and its dependence on optical properties will be investigated. Second, the analysis will be extended to the seasonal mixed layer development. Finally, the role of penetrating irradiance on the heat budget of the low-latitude ocean will be examined with a focus on interannual variation. Geographical areas of interest are the North Atlantic and the Equatorial Pacific.

### 5.24 Mark E. Luther

#### *Incorporation of SeaWiFS Data into Coupled Physical/Biological Models of the Arabian Sea*

A numerical model of the wind-forced circulation of the Indian Ocean coupled to a photosynthetic-irradiance model and an ecosystem model will be used to assimilate and interpret SeaWiFS ocean color data in the investigation of the intense upwelling and associated primary production that is observed in the northwestern Arabian Sea during the southwest monsoon. The physical model is

described in Luther and O'Brien (1985) as modified and extended by Jensen (1990, 1991) and J. Capella (pers. comm.). Extensions of the model are underway to include explicit mixed-layer processes. The photosynthesis-irradiance model of Platt and Sathyendranath (1991) and the ecosystem model of Walsh et al. (1989) will be coupled to the physical model to allow a more in-depth investigation of the upwelling process and its effect on sea surface temperature (SST), biological primary production, and the oceanic carbon budget in this region. We will quantify the dependence of the P-I parameters on physical factors such as mixed layer depth and nutrient supply by comparing these two physical/biological models. The model will be useful in the analysis of satellite and *in situ* observations, allowing interpretation of point measurements in a broader framework in both space and time.

### 5.25 Satsuki Matsumura

#### *Seasonal and Long Period of Time Variation of Phytoplankton Biomass and Primary Productivity on North West Pacific and Japan Sea*

Northwestern Pacific off Japan Islands and Japan Sea are well known as an area of highly variable oceanic conditions. Northern parts of those areas are covered by subarctic water which is characterized as Plankton rich water. Southern part are covered by oligotrophic subtropical water. Those water mass are divided by strong boundary and the boundary area is called as perturbed area.

We will investigate the mechanism of temporal variation of primary productivity in those area using chlorophyll map from SeaWiFS and ship observation.

Our goal of proposed research is to verify the spring phytoplankton bloom in the Japan Sea and resolve mechanisms which govern the time of inception, magnitude, and duration of spring phytoplankton bloom in the entire Japan Sea.

The mechanism of primary productivity maintenance by wind will be investigated using SeaWiFS data, NOAA AVHRR data, wind data and ship observations.

Five research vessels belong to fisheries institute will be used for field measurement, like as under water optical measurement, *in situ* primary production measurement using  $^{13}\text{C}$  method, plankton sampling for higher trophic level productivity analysis and water sampling for pigment extracting.

Fishing information will also be corrected by fisheries information systems for analyzing the relationship between fish stocks and primary productivity.

The relationship between oceanic conditions, primary productivity and more higher trophic level productivity will be clarified by SeaWiFS data and ship data.

Various kinds of sea-truth data including vertical profile will be provided from those areas in order to develop and validate the algorithm of chlorophyll evaluation from SeaWiFS.

The primary productivity in those area will be mapped using by available SeaWiFS data and ship data. And also, study on the mechanism of temporal variation of chlorophyll distribution and primary production related to oceanic condition will be progressed.

Successful results will contribute not only to evaluate mechanism of survival of fish larvae in the Japan Sea but also to provide data to analyze global environmental effects on primary productivity in the ocean.

## 5.26 Charles McClain

### *Physical-Biological Interactions in the Global Equatorial Surface Layer*

This proposal is in response to the NASA Research Announcement (NRA), *Sea-Viewing Wide-field-of-view Sensor (SeaWiFS) Global Ocean Primary Production*. The specific objectives of this proposal are to study the couplings between biological and physical processes, including primary productivity, and seasonal and interannual variability of these processes in the global equatorial ocean between  $\pm 30^\circ$  latitude. The approach will use an extensive assortment of satellite and *in situ* observations with coupled physical and biological models. The research program will integrate the related activities of the investigators in a diverse suite of field and satellite projects into a program responsive to the NRA objectives. These related efforts include the Joint Global Ocean Flux Study (JGOFS), the Global Ocean Ecosystems Dynamics program (GLOBEC), TOPEX/POSEIDON, the Earth Resources Satellites (ERS-1 and ERS-2 altimeters and scatterometers), the Tropical Ocean Global Atmosphere program (TOGA) and NSCAT.

## 5.27 André Morel

### *SeaWiFS Data as Input in Mapping and Modelling Global Carbon Fluxes*

The major goal of the present proposal is to develop methods for combining multiple satellite data sets and ultimately to assimilate such data into 1-D, then 3-D physical-biogeochemical models. The general objective is to analyze and understand, in order to be able to predict, the fluxes of organic matter leaving the upper layers of the ocean and correlatively to quantify the  $\text{CO}_2$  exchanges at the atmosphere ocean interface. The use and interpretation of remotely sensed data, in particular those delivered by SeaWiFS, which are essential in the problem addressed, will parallel the effort in process modelling. The validation of the entire system (data acquisition, interpretation and then assimilation in models) by using *in situ* measurements (permanent stations, or cruises) is also an imperative corner stone.

The thermodynamical (or solubility) pump would be the only mechanism regulating the  $p\text{CO}_2$  distribution in

an abiotic ocean, or as well in an ocean where all organic materials produced within the upper layers would be herein consumed (no export production). In the real ocean, the biological pump, which, on average, maintains negative  $\Sigma\text{CO}_2$  patterns, superimposed on what would result from the sole physical forcings. Ocean color is the unique formation, amenable to a detection from space, which can be related to the biological activity and therefrom to its impact on carbon flux and exchange. The simultaneous running of the two pumps requires that both biological and physical aspects be simultaneously contemplated. Sea surface temperature, wind field, currents and solar irradiation, in particular, are parameters, also measurable from space, which are needed in the physical segment of the study.

The French JGOFS program actually has adhered to this interdisciplinary philosophy and its Scientific Committee has strongly encouraged the development of a series of interwoven models to be validated via dedicated cruises. Specific processes studies and acquisition of pertinent data at the adequate spatial and temporal scales, (including sediment traps deployments) are the goal of these JGOFS cruises. The rationale for the EUMELI cruises (5 cruises from 1990 through 1993) and for the following OLI-PAC/FLUPAC cruises (Dec. 1993–1994) was formulated along these lines and the use (or actually the “preparation to a meaningful use”) of future ocean color sensor data, was explicitly stated in the preparatory documents. The suite of models to be validated begins with a productivity model, fed with the upper layer pigment concentration, that is the basic information delivered by an ocean color sensor.

Therefore the scientific community organized around the French JGOFS program, has naturally been highly responsive to the SeaWiFS announcement. This interest results in the present multifaceted proposal. Its intent is not to cover all French activities relying on the use of SeaWiFS data; rather, potentially significant contributions have been selected and will be presented as sub-proposals. They emanate from distinct groups, namely from:

*Laboratoire de Physique et Chimie Marines (LPCM),  
in Paris and in Villefranche-sur-Mer*

This Laboratoire depends from Université Pierre et Marie Curie (Paris 6) and is “Unité Associée au CNRS” (UA 353).

*Director:* A. Morel (Professor)

*Adjoint-Director:* A. Poisson (Directeur de Recherche CNRS)

*Laboratoire de Modelisation du climat et de  
l'Environnement, (LMCE) in Gif-Sur-Yvette*

This Laboratoire, newly created, depends from CEA the Commissariat à l'Energie Atomique.

*Director:* C. Laj (Ingenieur CEA)

*Laboratoire d'Océanographie et de Dynamique  
du climat, (LODYC) in Paris including a team  
depending from ORSTOM*

This Laboratoire depends from Université Pierre et Marie Curie and is a "Unité Mixte de Recherche" (UM 121), that means an Association between the University-CNRS and ORSTOM.

Director: L. Merlivat (Directeur de Recherche CNRS)

*Groupe de Recherche de Geodesie  
Spatiale (GRGS) in Toulouse*

This Laboratoire is a "Unité Mixte de Recherche" (UM 39), that means an Association between CNRS and CNES.

Director: J.F. Minster, "Physicien" at Observatoire Midi-Pyrennees

Between these groups, there exist many exchanges and well established cooperations under the JGOFS or PNEDC (CO<sub>2</sub> and WOCE Programs) umbrella and also thanks to a European contract ("air-sea CO<sub>2</sub> exchange," MAST ESTEC). These teams share data sets and models and often they take part in the same cruises or experiments. They, however, have specific objectives and particular strengths, as reflected by the separate sub-proposals.

Most of these sub-proposals are related to field activities and approved cruises, with the consequence that they can appear scattered in the world ocean. These French JGOFS cruises are oriented toward process studies in typical oceanic systems with the aim of validating a set of models of general use, allowing a meaningful extrapolation to be made in the future with the help of satellite information. They are not geographically oriented, so that the sub-proposals cannot be unified from this viewpoint. Also related to several sub-proposals, some WOCE cruises, will take place in various parts of the ocean, according to a strategy agreed upon at the international level, and the same remark as above applies. The connection between the sub-proposals being not in geography, the overall link is in the conceptual approach (that of JGOFS, summarized in the citation reproduced in the next section), whereas the differences correspond to a specialization of the teams and emphasis put on a specific aspect of the general problem addressed in the present proposal.

## 5.28 James L. Mueller

*SeaWiFS Pigments, Primary Productivity and  
Sedimentation of Organic Matter in the Gulf  
of California, and the El Niño-Southern  
Oscillation Cycle*

We propose to obtain continuous, basin-scale estimates of primary productivity by combining SeaWiFS time series of surface pigment concentrations in the Gulf of California with ship-based characterization of local bio-optical

provinces in terms of vertical pigment and irradiance attenuation structure, direct measurements of photosynthesis vs. irradiance parameters and *in situ* productivity, and continuous estimates of pigment concentration and primary productivity from moored natural fluorometers. Our goal is to establish quantitative relationships between the rates of primary productivity and deposition of organic matter into the anoxic varved sediments on the continental slope of the Gulf of California near Guaymas, Mexico. The annual strata preserved in these sediments provide a chronological record of the climatic El Niño cycle in the Eastern North Pacific. Quantification of the relationship between production and sedimentation of organic matter will allow interpretation of the record preserved in the sediments and advance understanding of the effect of seasonal and interannual changes in physical and biological processes in the upper ocean on organic carbon sedimentation in sites such as these. We will undertake this research in collaboration with the SeaWiFS research proposed by Drs. Ruben Lara-Lara, Tim Baumgartner, Saul Alvarez-Borrego, Helmut Maske, and Gilberto Gaxiola-Castro of the *Centro de Investigación Científica y de Educación Superior de Ensenada* (CICESE) in Ensenada, Mexico. CICESE will provide ship time for approximately quarterly bio-optical cruises in the Gulf of California, analyses of concurrent sediment trap samples from a deep moored trap near Guaymas (part of an ongoing long-term study Dr. Baumgartner at this site), *in situ* productivity, and other ancillary biological and chemical analyses.

## 5.29 Frank E. Muller-Karger

*Evaluation of Regional and Temporal  
Variation of Primary Productivity  
within Case II Ocean Shelf  
Waters Using SeaWiFS*

Global estimates indicate that 30% of oceanic primary production occurs in shelf waters that represent only 10% of the ocean surface. However, satellite-derived estimates of shelf production in tropical and mid-latitudes appear to be higher than ship estimates by a factor of 2 to 5. This discrepancy alone could lead to a 30–80% overestimate of global ocean production. We propose to study this issue by measuring production in shelf waters and testing regional algorithms with SeaWiFS imagery. Our working hypothesis is that default parameters in open ocean productivity algorithms lead to shelf production overestimates. This in turn affects global area-weighted production estimates. The primary goals of this research are to:

- 1) Quantify the role of continental margins in the global cycles of biogenic elements using satellite data. We will focus on corrections for non-viable colored compounds (e.g. dissolved organic carbon and phaeopigments) in shelf and river plumes.

- 2) Investigate the physical and chemical factors that control production and its variability on continental margins, and quantify this variability using remotely-sensed estimates of phytoplankton distribution.
- 3) Investigate the trajectory of materials supplied via upwelling and river discharge.
- 4) Coordinate science activities with the SeaWiFS Science Team, provide support to the SEASDIS, and ensure data compatibility for SEASDIS distribution.

During 1993–1996, we will make bio-optical and productivity observations on two cruises per year to diverse shelf environments. We will examine the plumes of the Chesapeake Bay, Orinoco River, and Mississippi River in consecutive years, and conduct annual cruises to the West Florida shelf. Observations include surface and subsurface spectral reflectance, photosynthetic pigments (HPLC),  $^{14}\text{C}$ -based productivity (spectral  $P-I$ ), DOC, and  $\text{NO}_3$ -nitrogen assimilation using  $^{15}\text{N}$  tracer. In preparation for the SeaWiFS launch, historical bio-optical and CZCS data for these areas will be assembled into a working database.

Institutional support for this research is considerable: USF provides HRPT antenna coverage, annual cruises to the West Florida Shelf and Mississippi plume are provided by the Florida Institute of Oceanography and the Florida Department of Natural Resources, and the NSF-funded LMER program at the University of Maryland provides productivity data and ship time in the Chesapeake plume in 1993. Sampling of the the Orinoco plume will be carried out using Venezuelan vessels in 1994. Airborne LIDAR and ODAS observations will help define sub-pixel variability and atmospheric effects during SeaWiFS overflights.

The expected results are test-case productivity models encompassing regional and temporal variation of global margins, to be applied using GAC and selected LAC SeaWiFS data. The work complements ecosystem simulations proposed by John J. Walsh in response to this NRA, and the SeaWiFS, MODIS, and HIRIS algorithm work of Kendall Carder. The joint research ensures preservation of a multi-decade series of satellite observations of shelf waters (CZCS, SeaWiFS, OCTS/ADEOS, MERIS, MODIS, and HIRIS).

### 5.30 Egil Sakshaug

#### *Validations and Applications of SeaWiFS Data in the Nordic Seas*

This proposal embodies calibration of SeaWiFS data and Norwegian scientific applications of SeaWiFS data. The data will be used in Norwegian national ecological and climate research programs covering the Greenland, Iceland, and Norwegian (GIN) Seas, the Barents Sea, The Norwegian Coastal Current, the North Sea Skagerrak and

Kattegat and will be used in mathematical ecosystem models which are being generated for these areas. These research programs include studies on the biological carbon pump as well as systems ecology ranging from primary productivity via zooplankton to commercially important fish species, as well as effects of pollution in coastal waters. The SeaWiFS calibration-related part of these programs will comprise bio-optical studies for the development of algorithms. While waters in the GIN and the Barents Sea generally are blue, except when rich in phytoplankton, Norwegian coastal waters generally are green (Case II waters) due to humus- and particle-laden waters from rivers and, in particular, from the Baltic Sea. In extreme cases this greenness may correspond to  $10^{-15}$  mg Chlorophyll  $a\text{ m}^{-3}$  in blue waters (on basis of standard CZCS algorithms). An important part of the studies therefore is to construct regionally validated algorithms for resolving various water constituents (biogeneous pigments, suspended sediments and dissolved yellow substances). Moreover, by having a multi-wavelength sensor, SeaWiFS might distinguish between prominent algal classes or species, for instance diatoms from *Phaeocystis pouchetii* and *Emiliania huxleyi* as well as blooms of harmful algae, due to the different optical characteristics of these algae.

### 5.31 Frank A. Shillington

#### *Analysis of Ocean Colour Data from SeaWiFS in the Ocean Around Southern Africa for Fisheries and Climate Research*

This proposal seeks to use LAC SeaWiFS ocean colour data for the continental shelf region of the Benguela Upwelling Current System off the west coast of South Africa and the Agulhas Bank region south of Africa, to elucidate details of the primary production of the area and hence improve the knowledge of the food chain for pelagic fish species of the area. The project aims to collect detailed *in situ* measurements of a wide range of parameters e.g., T, S, chlorophyll  $a$ , PI) and their depth characteristics so that these can be related to satellite measures of colour. The sea measurements are being made as part of ongoing studies of phase III of the South Africa funded Benguela Ecology Programme (BEP) on the west and south coasts of Africa.

In the Southern Ocean, the South African funded Antarctic Marine Ecosystem and Climate Change Programme will have regular research cruises to the subtropical convergence and subantarctic front south of Africa. The approach in this programme is to make photosynthesis and irradiance measurements in order to delineate the different bio-optical provinces along the lines recently explored by Platt et al (1990). Size fractionated  $^{15}\text{N}$  uptake and regeneration experiments will help to measure the “new” production and thus provide an estimate of vertical carbon flux.

Both the BEP and the Antarctic Marine Ecosystem and Global Change programmes will provide regional contributions to JGOFS, WOCE and GLOBEC.

### 5.32 David A. Siegel

#### *Inherent Optical Property Inversion of SeaWiFS Ocean Color Imagery*

We propose to investigate new methodologies by which SeaWiFS ocean color imagery may be used to study upper ocean ecosystem dynamics. The approach will be to invert both SeaWiFS and *in situ* ocean color observations to obtain spectral estimates of biogeochemically relevant inherent optical properties (IOPs), such as coefficients for phytoplankton and detrital absorption and particulate backscatter. We also propose to compare the inversion results with detailed *in situ* IOP observations.

The proposed work will be made in conjunction with ongoing ocean optics profiling investigations made at the U.S. JGOFS Bermuda Atlantic Time-Series Station (BATS). Approximately 20 BATS cruises are made each year to a site about 75 km SE of the Bermuda Islands. The coupling of the inherent seasonal and interannual variability of the BATS site and the high quality biogeochemical and optical observations presently made at BATS with the specific IOP determinations proposed here will produce a spectacularly rich data set for the analysis and modeling of ocean color variability.

The goals of the proposed work are to:

1. Use *in situ* reflectance observations to develop an IOP inversion method,
2. Determine relevant *in situ* IOPs as part of the regular BAT observations,
3. Evaluate the correspondence between the IOP inversion results and *in situ* observations,
4. Apply the IOP inversion to SeaWiFS imagery for the Sargasso Sea in order to investigate spatial and temporal variability of upper ocean ecosystem properties.

The exciting result from the proposed work is that the IOP inversion method will allow a variety of biogeochemical processes to be directly assessed from SeaWiFS data that are presently unobtainable. For example, the amount of photosynthetically usable radiation (PUR) may be directly determined using the IOP inversion procedure as can the relative concentration of viable algal biomass. Changes in algal community composition, as well as algal photoadaptation processes, may also be assessed by examining changes in spectral absorption or backscattering estimates.

In some sense, we are proposing to look at ocean color remote sensing backwards. That is, it is not our goal to determine chlorophyll *a* concentrations from SeaWiFS imagery. Instead, our aim is to determine ecologically-relevant inherent optical properties from the SeaWiFS

data. The subsequent comparison of our results with the standard SeaWiFS data products (cf., chlorophyll *a*) should prove to be very fruitful.

### 5.33 Philip Slater

#### *SeaWiFS Calibration and Algorithm Validation*

To obtain multispectral values of ocean reflectances and downwelled spectral irradiances requires first, the conversion of the recorded digital counts into radiances, and second, accurate correction for atmospheric effects. The onboard calibration of SeaWiFS will be realized by referencing a solar-diffuser panel and viewing the moon, these should provide a good check of sensor stability but not necessarily of absolute radiometric calibration.

The first part of this proposal concerns verifying the onboard calibration results with vicarious calibrations that associate digital counts to predictions of incoming radiance at the time of overpass. Two test sites shall be used: Edwards Air Force Base (EAFB), routinely used for the calibration of other sensors, during the winter months for all channels, except 4, 5, and 6 which will saturate, and Lake Tahoe, during the summer months for all channels. The procedures to be used will be slightly modified versions of those used at EAFB, White Sands and Maricopa Agricultural Center. However, we shall also evaluate a "Rayleigh calibration" for the short-wavelength channels that takes advantage of the predominance of molecular scattering.

The second part of this proposal concerns the validation of atmospheric correction procedures, such as those developed for CZCS and algorithms for chlorophyll *a*, colored dissolved organic matter, and bathymetry. We propose to apply these procedures to SeaWiFS images of Lake Tahoe. We shall first compare the SeaWiFS-derived water reflectances and downwelled irradiances with our measurement results. We shall then analyze each step of the atmospheric correction procedure by comparing derived atmospheric parameters to actual measurement results. Finally, these results shall be compared to *in situ* water measurements.

We believe the combination of proven accurate land, water and atmospheric measurements for satellite calibration and reflectance retrieval, innovative measurements of BRDF from low-altitude aircraft and of aerosols using a new CCD aureole camera, together with a strong background in modeling, will provide valuable baseline data for calibration/validation and related determinations of pigment concentration in surface waters.

### 5.34 Raymond C. Smith

#### *Bio-Optics, Photoecology and Remote Sensing Using SeaWiFS*

An important component of the recent plans to understand the earth as a system (EOS Reports 1988) includes

the Joint Global Ocean Flux Study (JGOFS) which has as its long-term goals: “1) To evaluate and understand on a global scale the processes controlling time-varying fluxes of carbon and associated biogenic elements in the ocean, and 2) To develop a capability to predict the response of oceanic biogeochemical processes to climate change.” As has been frequently noted the “G” in GOFs/JGOFS requires linked satellite and surface observations in order to accurately and continuously achieve GLOBAL coverage. The work proposed herein would extend and complement three interdisciplinary process oriented studies, in different ocean locations, by making use of untended moored optical sensors to provide proxy estimations of pigment biomass and phytoplankton production. High quality optical surface data, obtained simultaneously with SeaWiFS imagery, will provide these proxy estimates across a range of space/time scales and with higher accuracy than would otherwise be available without multiplatform sampling. The common theme of these studies is to investigate and understand factors responsible for production, transport and fate of biogenic material. This work is expected to enhance the usefulness of SeaWiFS data and, in particular, to lead to improved methodologies for the regional and global estimation of pigment biomass and primary production using combined untended mooring and ocean color satellite data.

### 5.35 Boris Sturm

#### *Alternative Methods for the Determination of Optically Active Material Concentrations in Marine Water*

The main problems in processing optical remote sensing data from coastal waters today arise from difficulties in the aerosol atmospheric correction due to spatial variation of the Ångström exponent (AE), and from uncorrelated variations of the optically active materials (OAM), i.e., chlorophyll-like pigments, total suspended matter and dissolved organic matter. The improved performance of SeaWiFS with respect to CZCS will allow a considerable improvement in the atmospheric corrections and in the retrieval of OAM concentrations. It is proposed to develop a new set of atmospheric and pigment (level-2) algorithms for SeaWiFS data, based on the use of generalized water optical models, giving the subsurface reflectance, as a function of all OAM, in a minimization procedure that will determine AE and OAM concentrations on a pixel-by-pixel basis. The AE map (or its smoothed version) can optionally be used to evaluate subsurface reflectance in the six SeaWiFS spectral channels, applying the Gordon approach for atmospheric correction with known AE. Sky and sun glitter effects and Rayleigh-aerosol interactions will be accounted for. In this case the retrieval of OAM concentrations from the spectral subsurface reflectance can be performed by various methods: i) inversion techniques

based on the generalised water model; ii) *intelligent* band algorithms; and iii) principal component analysis.

### 5.36 Neil W. Tindale

#### *The Remote Sensing of Mineral Aerosols and Their Impact on Phytoplankton Productivity Using SeaWiFS*

Our main objective is to use the SeaWiFS data to image (or locate) and quantify continental aerosols including mineral aerosols, over open ocean regions and to investigate whether SeaWiFS data can be used to study the relationship between mineral aerosols, their input to the open ocean surface waters and phytoplankton productivity. Combining the SeaWiFS aerosol data with the SeaWiFS ocean color data will allow us to directly study the effect of atmospheric mineral particle input on open ocean productivity. This proposed work is the expansion of our present NASA funded study that uses the existing CZCS image [ $L_a(670)$  channel] database. Using the SeaWiFS data as opposed to the existing CZCS images will provide spatial and temporal coverage of aerosol conditions in near real-time as well as increase the number of aerosol channels. This will allow us to compare remotely sensed concentrations of aerosols with measured concentrations at existing atmospheric sampling stations worldwide. This will then give us the ability to study aerosol transport, concentration and fluxes over and into open ocean surface waters particularly for regions where there are no sampling stations nearby. In addition to the mineral aerosol input-productivity question, we intend to use the SeaWiFS data to study atmospheric issues such as atmospheric transport and aerosol distributions, aerosol ageing processes (including residence times), atmospheric chemistry of aerosols, and aerosol optics. The availability of the SeaWiFS data will also give us the ability to study real-time processes (such as volcanic eruptions) that can radically alter aerosol concentrations.

We also intend to participate in several field studies as part of this proposal. These anticipated field studies are part of existing proposed studies and include the Iron Patch Experiment off the Galapagos Islands (Fall, 1993), the JGOFS Arabian Sea Process Study (Fall, 1993–1994) and the JGOFS/IGAC Southern Ocean Process Study proposed to start in early 1995. We also hope to participate in atmospheric sampling initiatives associated with the North Atlantic atmospheric monitoring program AEROCE. All these field programs would give us good opportunities to use the SeaWiFS data to study specific processes and to also provide validation data for different regions. The actual experimental work during these field studies would include measurements of aerosol concentrations, fluxes and optical properties as well as phytoplankton biomass and productivity in surface waters using conventional methods and rapid profiling optical sensors.



To summarize, the results from our proposed study will improve our understanding of the coupling between aerosol micronutrient transport and input to the open ocean and of the relationship between aerosol input and surface water productivity. It will also provide information on atmospheric processes including atmospheric transport and mixing, aerosol aging, aerosol optics, and thus the role of aerosols (and clouds) on atmospheric radiative properties.

### 5.37 Charles Trees

#### *Bio-Optical Properties of the Arabian Sea as Determined by In Situ and SeaWiFS Data*

We propose to characterize relationships between remotely sensed ocean color and the vertical profiles of bio-optical variables and primary productivity—and their interannual and seasonal variabilities—to address central goals of the U.S. JGOFS Arabian Sea Process Study. We hypothesize that photoadaptation by phytoplankton creates vertical profiles of pigments and optical profiles which, in a given geographic province and time of year, are predictable functions of near-surface optical properties estimable from remotely sensed ocean color. We further speculate that the joint profiles of natural and stimulated fluorescence and optical properties are photoadaptive characteristics which may correlate with primary productivity. We propose to acquire optical and fluorescence (natural and stimulated) measurements during U.K. PRIME Arabian Sea cruises, which in combination with their core measurements of pigments and productivity, will be used to develop empirical models of these relationships. These results will enable pigment biomass and productivity analyses of SeaWiFS ocean color data, as well as contributing to the assessment of regional biogeochemical processes in the context of the overall JGOFS Arabian Sea data set.

### 5.38 Ümit Ünlüata

#### *A Comparative Study of Primary Productivity, Transport, and Shelf-Open Sea Interactions in the Black Sea, Based on the SeaWiFS and CZCS Data*

The Black Sea is a unique enclosed basin threatened by eutrophication processes. It is a region of moderate to high productivity compared to the world ocean, but a series of catastrophic changes in the functioning of its ecology have occurred over the last decades, prompting a number of intense research activities in the 1990s.

The proposed research program will address the impact of rapid ecological changes on the productivity of the Black Sea by comparing the SeaWiFS data with the CZCS data of the previous decade.

Comparisons of average (monthly or seasonal) productivity parameters computed from several years of time series of satellite data will yield information on the ecological

changes in the last decade, and help identify interannual changes, known to be important in the region. It will also give an opportunity to compare the performance of computation algorithms used for both data sets and beta test SeaWiFS algorithms. Other scientific outputs will define the effects on primary productivity of the coastal-open sea interactions, relations with circulation features, river mouths, bays and straits. The important roles of rapid, dynamical processes have been demonstrated in the region based on a synthesis of experimental results and satellite data.

### 5.39 John J. Walsh

#### *Simulation Analysis of Dissolved and Particulate Components of the SeaWiFS Color Within Case-II Waters*

Past and future estimates, involving satellite color imagery, of primary production and carbon cycling by the marine biosphere are aliased by CDOC and phaeopigment contaminations of the CZCS and SeaWiFS signals, particularly in Case-II shelf waters. Using coupled biophysical models of the time-dependent response of marine food webs to physical perturbations of their habitat, the seasonal dynamics of two surface color plumes will be examined within otherwise oligotrophic ecosystems, in which distinct terrestrial (Caribbean basin) and marine (West Florida shelf) sources of DOC may predominate. The explicit state variables of the biological models would be CO<sub>2</sub>, DOC, NH<sub>4</sub>, NO<sub>3</sub>, N<sub>2</sub>, light phaeopigments, the chlorophyll stocks of diatoms, dinoflagellates, coccolithophores, cyanobacteria, and the organic carbon content of macroaggregates, fecal pellets, and sediment detritus. The implicit components of these biochemical food webs would be wind, temperature, total and borate alkalinities, salinity, calcium, protozoan and copepod herbivores, bacterioplankton, and benthos on the West Florida shelf.

Within these basin and shelf ecosystems, the biophysical models will 1) distinguish between the dissolved and particulate components of the CZCS and SeaWiFS radiance signals, 2) provide resolution of the fates of the terrestrial and marine sources of CDOC, and 3) partition the particulate color component into phytoplankton debris (phaeopigments) and live functional groups. Until SeaWiFS is launched in fall 1993, the existing current meter, drifter, pigment (fluorometric and HPLC), DOC (ultraviolet and platinum), and CZCS data (1979–1981) in the southern Caribbean (Orinoco River Plume) and the northern Gulf of Mexico (West Florida Plume) would be used for initialization of the models. During 1994–1996, concurrent measurements of HPLC pigments and DOC<sub>pt</sub>, as well as <sup>14</sup>C and <sup>15</sup>N uptake, would be made at bimonthly intervals on the West Florida shelf during overflights of the SeaWiFS, with semi-annual sampling of the Orinoco River plume, for validation of the simulation models.



## 5.40 Leif Wastenson

### *Remotely Sensed Ocean Color in Support of Studies of the Carbon Cycle in the Baltic and the North Atlantic Pelagial*

Imagery from the Sea-viewing wide-field-of-view sensor (SeaWiFS) ocean color data is requested for support of ongoing projects to assess aspects of carbon cycling and mass transport in the Baltic Sea and the Azores Current area in the North Atlantic pelagial.

We propose to use time series of SeaWiFS images (phytoplankton pigments, total suspended matter, sea-surface temperature) in addition to continuous transects of *in situ* data and in comparison with NOAA AVHRR imagery to:

- 1) Detect inter-annual trends, spatial distribution patterns and triggering mechanisms of harmful plankton blooms in relation to eutrophication in the Baltic Sea and the Skagerrak;
- 2) Test the ability and limitations of the NOAA AVHRR archives to detect surface plankton blooms in the Baltic Sea;
- 3) Assess the influence of plankton size structure on the pathways of carbon cycling (sedimentation versus recycling) in the Baltic Sea and the Azores Current area;
- 4) Test the ability of different SeaWiFS algorithms to cope with changes in the intensity of scattering versus absorption due to drastically different plankton size structure as well as with interference from colored dissolved organic matter;
- 5) Assess the influence of sea-surface fronts on the primary production and pigment concentration in the Baltic Sea; and
- 6) Assess aspects of the coastal-offshore exchange of matter, including the influence of different coast types (archipelagos, rugged or straight coastlines).

The requested SeaWiFS scenes over the Baltic Sea should preferably cover at least the time period March–October with maximal frequency allowed by the cloud cover, the scenes from the Azores Current area (21° W; 32.5° N) should cover March–April.

## 5.41 Marcel R. Wernand

### *Relation Between Particulate Matter and North Sea Colour for use With SeaWiFS*

Knowledge of the concentration, dispersal and composition of plankton and suspended matter in the North Sea is of great importance for adequate describing and monitoring this ecosystem. Input of fresh river water containing particulate matter and abundant nutrients in the aquatic region is an important economic topic for fisheries and for

pollution control. Traditional methods to measure biogeochemical parameters in coastal seas only provide information on isolated points. For synoptic mapping of these areas optical remote sensing offers the overviews needed for qualitative and quantitative modelling.

Between 1987 and 1994 the optics and remote sensing group of The Netherlands Institute for Sea Research is and will be intensively monitoring the Dutch coastal water throughout the year for optical properties. Spectral sea water signatures are being analyzed with respect to optical remote sensing applications. Emphasis is on the interpretation of coastal water reflectance spectra in relation to the suspended and dissolved sea water constituents. So-called Case 2 water algorithms were developed for CZCS, NOAA AVHRR and the coming SeaWiFS satellite scanner (Marees, Wernand 1991). The relationships were established by means of a 22-channel radiometer and applied on and tested with our airborne line spectrometer (CORSAIR).

A new research program funded for 3 years by the Dutch Remote Sensing Board (BCRS), started this July to tune algorithms found earlier for the North Sea. This will be a biogeological program in close cooperation with the Tidal Water Division of Rijkswaterstaat, University of Groningen (RUG, Gieskes), CEMO and the University of Southampton (Boxall).

Experience in the application of algorithms on satellite images will be gained with the CZCS data set within a demonstration program in the ESA/JRC Ocean Colour European Archive Network (OCEAN). The corrected (geo., atmo.) CZCS data over the operating period will be available by the end of 1992.

Expertise in the sampling of remotely sensed aircraft data is gained as participant in the French/Anglo FLUX-MANCHE program. Accurate algorithms, found earlier for the Irradiance Attenuation Coefficient among other water quality parameters in the Dutch coastal North Sea were used to derive bio-optical parameters of the area concerned.

The results will consist of archives of optical data for the North Sea and water quality algorithms for Case 2 water applicable on SeaWiFS data. The synoptic data from RS on chlorophyll and suspended matter will be used to validate the North Sea ecosystem models on a temporal and spatial basis. A special tool will be developed to compare the outcome of the ecosystem models with RS data.

The relevance of SeaWiFS is that it presents the possibility of intercalibration of the SeaWiFS sensor by means of spectral ground truth instrumentation in the North Sea during sea going expeditions. Starting with sea going programs and aircraft remote sensing back up in 1993 before the launch of SeaWiFS and continue with the development of SeaWiFS dedicated algorithms in the post-launch period. A study will be conducted of the applicability of SeaWiFS data in ecological and suspended matter modelling.

## 5.42 Charles S. Yentsch

### *The Determination of the Two Pathways of Primary Production by SeaWiFS Colorimetry*

The ecological significance of the concept of “new production” is the paradigm for two pathways of primary production, namely nitrate advection and nitrogen recycling. These pathways are associated with the presence or absence of stratification of the water column which is reflected by changes in the mean cell size of phytoplankton populations and the pattern of carbon flux through the food web. The change in cell size is important to the estimate of new production since the effectiveness of the biological pump depends upon the fate of the fixed carbon. We cannot accurately estimate new production without knowledge of the temporal scales of carbon flux through the main food web.

To use the SeaWiFS colorimeter to measure the two pathways of new production requires algorithms which not only measure chlorophyll but also estimate the mean cell size of phytoplankton populations. It is proposed that mean phytoplankton cell size can be measured optically and that this information can form the basis for developing algorithms. The basis of the optical information is derived from pigment packaging/cell size relationships.

The proposed research requires bio-optical measurements in the laboratory on algal cultures and field measurements in several regions of the world's oceans. The ultimate goal is to identify regions of the oceans according to new production pathways using products derived from SeaWiFS.

## 5.43 James Yoder

### *Processes Affecting Primary Productivity of Open Ocean and Ocean Margin Waters of the Northwest Atlantic*

My goals are to process, analyze, and archive full resolution (local area coverage or LAC) SeaWiFS imagery downlinked to the HRPT station at NASA Goddard to:

1. Develop a 3-year time series of level-3, full resolution ( $1 \times 1$  km) SeaWiFS chlorophyll imagery mapped over ocean margin waters off the U.S. East Coast;
2. Validate the SeaWiFS-chlorophyll algorithm for ocean margin waters off the U.S. East Coast;
3. Make key contributions to understanding the dynamics of phytoplankton biomass (SeaWiFS-chlorophyll) and primary production in shelf, slope and open ocean waters off the U.S. East Coast; and most importantly,
4. Develop and evaluate an approach that can be used to incorporate annual phytoplankton biomass and primary production cycles occurring within ocean margin waters off the U.S.

East coast into basin-scale models of biogeochemical cycles in the Atlantic Ocean.

To accomplish these objectives, I will also use AVHRR SST imagery; in-water optical and pigment measurements acquired by me using protocols recommended by the SeaWiFS Project; various other hydrographic, pigment, primary production, nutrient and meteorological data collected and archived by my collaborators and a mixed layer model developed by Dr. P. Cornillon's NASA Scatterometer (NSCAT) project.

Ocean margin waters cover less than 20% of total ocean area, but their importance to carbon and nitrogen cycling is proportionately higher, because rates of biological processes (e.g. primary production) are proportionately higher in comparison to mean conditions in the open sea. Estimates of primary production (net rate of organic carbon production) in margin waters range from about 30 to 50% of total ocean primary production, which in turn is 30 to 40% of the total primary production of the biosphere.

Temporal and spatial patterns of phytoplankton biomass and primary production are highly variable in ocean margin waters, and day-to-day variations are uncorrelated over ca. 100–200 km distances. These and other characteristics of ocean margin waters make it difficult to accurately incorporate their contributions within ocean basin-scale models of biogeochemical cycles. Although it is extremely important to study margin processes at their appropriate time scales of days-to-weeks and spatial scales of ten-to-hundreds of kilometers, numerical models and other quantitative analyses of ocean basin-scale processes operate on longer time and larger space scales. If ocean margin processes are to be accurately incorporated into basin-scale models, we need to develop the means to represent or approximate important dynamics in the margins without including all of the spatial and temporal variability. The accomplishment of my proposed research most directly related to the top priority of the SeaWiFS Research Announcement will be to develop and evaluate such an approach for annual cycles of phytoplankton biomass and primary production in margin waters off the U.S. East coast.

## 5.44 J. Ronald Zaneveld

### *A Study of the Inherent Optical Properties in Relation to Remotely Sensed Radiance*

The inherent optical properties form the link between the biogeochemical parameters and the remotely sensed radiance. The SeaWiFS sensor does not measure pigment concentrations directly, but only their influence on the upwelling daylight field. The IOP express the way in which the dissolved and suspended materials modify the daylight field via scattering and absorption. In this proposal we address the need to include knowledge of the inherent optical properties in the experimental and theoretical work associated with the SeaWiFS sensor. We propose theoretical studies to more accurately relate the remotely sensed

radiance (as expressed by the reflectance at the air-sea interface) to the scattering and absorption characteristics of the ocean water. We propose to participate in a number of cruises in order to measure the absorption and scattering spectra in conjunction with the apparent optical properties and biogeochemical parameters. We propose to test the reflectance relationships, and we will examine methods to directly predict the optical properties of the ocean from the water-leaving radiance. We will examine relationships between the absorption and scattering characteristics and characteristics of the dissolved and suspended matter.

Our objectives are:

1. To develop nearly exact reflectance models based on the equation of radiative transfer that include only measurable inherent optical properties and the lightfield at the sea surface. These IOP are the spectral absorption, attenuation and backscattering coefficients as well as the volume scattering coefficient at a few fixed angles.
2. To measure the IOP under item 1 on cruises on which the AOP and biogeochemical parameters are measured together with SeaWiFS coverage.
3. To evaluate the reflectance relations and other inversion algorithms using the *in situ* data.
4. To determine the accuracy with which the absorption coefficients may be obtained directly from the remotely sensed radiance using theory and the data set obtained under item 2.
5. To study the relationship between the backscattering and the biogeochemical parameters in order to arrive at a more accurate predictive model for the backscattering that can be used in the inversion of SeaWiFS data.

As a result of our work we will have a far greater understanding of the dependence of the remotely sensed reflectance on the absorption and scattering properties of the ocean. We will have made significant progress towards being able to invert the satellite sensor signal to obtain the absorption and backscattering characteristics of the ocean. These optical properties will be very useful in the determination of primary production, the concentration of inorganic particulates in coastal regions, the study of heat budgets in the ocean, etc.

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#### APPENDICES

- A. *In Situ* Data Policy
- B. Addition or Modification of Science Data Products for the SeaWiFS Data Processing System
- C. File Naming and Format Conventions for *In Situ* Data
- D. Responses to the SeaWiFS Questionnaire
- E. Attendees to the First SeaWiFS Science Team Meeting

#### Appendix A

##### *In Situ* Data Policy

This policy covers data submitted to the National Aeronautics and Space Administration (NASA) SeaWiFS Project Office (SPO) at Goddard Space Flight Center (GSFC) for inclusion in the calibration and validation data collection. Its purpose is to ensure that accurate *in situ*, shipboard, and airborne bio-optical measurements are made rapidly available to Science Team members (and other approved investigators) for advanced algorithm development and data product validation purposes, while ensuring that the observer or provider receives proper credit and acknowledgement for the considerable expertise and effort applied to obtaining and reducing the data.

**Submission:** Ocean color algorithm development is essentially observation limited, and rapid turnaround and access to such data is crucial for progress. Data obtained under contract should be submitted as soon as proper calibration information can be applied, and not later than six months from collection. Science Team members and other investigators making suitable observations are encouraged to provide their data as soon as possible. Data is expected to be submitted no later than one year following collection, or at the time of submission of any paper using the data by the provider. Investigators who make observations of bio-optical parameters are expected to submit their observations prior to accessing data from others.

**Access:** Access to the digital data will be limited initially to approved users as determined by the ST and the providers, for a period of one year following collection. Other investigators interested in obtaining such data will be referred to the provider for permission. Following an agreed upon period, data will be deemed public, and access will be unlimited. Records of distribution will be maintained and forwarded to the provider, and citation requirements set forth below still apply. Only information about the digital data (parameters, locations, dates, investigators, etc.) will be available for unlimited downloading or distribution.

**Use Conditions:** Users of data will be required to provide proper credit and acknowledgement of the provider. At minimum, this should be acknowledgement by name and citation of any works describing the data or its use. Citation should also be made of the data archive. Users of data are encouraged to discuss relevant findings with the provider early in the research. The user is required to give to all providers of the data of which he has made use, a copy of any manuscript resulting from use of the data, prior to, or coincident with, initial submission for publication. Within one year of data collection, the provider(s) shall be offered the right to be a named co-author.

**Updates and Corrections:** A major purpose of the database is to facilitate comparisons of absolute calibrations and protocols

between *in situ* observations (regionally, temporally, by technique, by investigator, etc.), as well as between *in situ* and remotely sensed observations. Updates and corrections to submitted data sets by the provider are encouraged. Records will be maintained of updates and corrections, summaries of updates will be posted on a database board, and users shall be notified of the updates. The methodology for doing this efficiently will probably have to be developed on a case by case basis. The current data in the archive should be identical with the data used in the provider's most recent publications or current research.

**Formats:** Data should be provided in an agreed-upon format, along with relevant information describing collection conditions, instrument performance and calibration, and statements of its accuracy. In general, parameters and units shall be as described in the Monterey Calibration/Validation Workshop Report, and recommended format is To Be Determined (TBD). Data values shall be in their final form, e.g., providing volts together with conversion coefficients and drifts is unacceptable. High level data sets are encouraged, for example, normalized water-leaving radiance spectra, together with descriptions of, or citations of, the procedures used to derive the values. Data should be segmented into rational sets, by station, date, parameter, etc. Data quality, calibration traceability and history, drift, and sampling protocols may be in text format. Listing of what criteria need to be treated should be developed by the Science Team.

**Record Keeping:** The SPO will maintain an accurate database of these data. All data will retain the investigator's identification, and any necessary quality control information, at the level of distribution. This necessitates that combined data sets from several investigators retain their individual identifications, if any such combining is done by the SPO. The SPO will maintain accurate records of distribution, and will inform the original provider of investigators requesting their data. The data will not be released for inclusion in other databases which do not agree to honor conditions set forth above.

W. Esaias December 12, 1991, rev. February 22, 1993.

## Appendix B

### *Addition or Modification of Science Data Products for the SeaWiFS Data Processing System*

This document addresses requirements for submission and approval of new or modified science algorithms to the SeaWiFS Project Data Processing System. Such additions or modifications are essential to maintain an up-to-date, high quality set of standard products. As more is learned about ocean color and atmospheric correction during the course of the mission, additions and modifications to the scientific procedures will naturally occur and must be incorporated in order to produce the best possible standard products. Since the Data Processing System is a finite and limited resource, proposed major changes and additions will need clear definition and firm justification. While primarily addressing the SeaWiFS Project activities, the principles might apply for any official NASA SeaWiFS derived product.

Proposed additions or modifications should first be brought to the attention of the SeaWiFS Project Scientist through a written proposal. The proposal should contain graphical and textual description of the algorithm, under what circumstances

(locations, times, etc.) it applies, the methodology for validation, and its potential importance to scientific problems.

The following positions or their representatives may be involved in the decision to approve or disapprove a new algorithm (the persons currently filling the positions are shown in parentheses):

- Headquarters Program Scientist (F. Muller-Karger),
- SeaWiFS Project Manager (R. Kirk),
- SeaWiFS Project Scientist (W. Esaias),
- SeaWiFS Algorithm Group (Table 1), or the full Science Team,
- SeaWiFS Calibration/Validation Leader (C. McClain),
- SeaWiFS Data System Manager (G. Feldman), and the
- GSFC or responsible DAAC Manager (S. Warton).

Along with the recommendation of the SeaWiFS Science Team, these persons will determine, based on their appropriate areas of expertise, the importance and feasibility of implementing the algorithm based on the criteria listed in the next section.

Additionally, the impact on the Goddard DAAC must be assessed, and their concurrence on archiving and distributing the data product must be obtained. This may require that the GSFC DAAC User Working Group grant their approval, and place the additional task within overall priority for DAAC resources. Finally, any additional Project or Project related resources that are needed must be identified.

The following criteria will be used to judge whether or not an algorithm should be added or modified:

1. **Publication:** Although submitted or well-tested algorithms may also obtain approval, documentation and publication in a peer-reviewed journal substantially increases the likelihood of approval. Use of rapid publications such as *Geophysical Research Letters* is encouraged. Implementation of an algorithm involves documentation and levels of detail that generally exceed what is suitable for the open literature, and the use of the *SeaWiFS Technical Report Series* for this purpose should be considered. Details such as coding requirements, boundary conditions, error trapping, setting thresholds, formats, procedures for quality assessment of the input and output products, and procedures for ongoing validation should be covered.
2. **Significance:** The ability of the algorithm to improve current products or to extend the use of SeaWiFS data into new areas of scientific concern should be a major factor in its selection. The potential demand by scientists within or outside the ocean science community should be considered. This decision is made primarily by the HQ Program Scientist, the SeaWiFS Project Scientist, and the Science Team.
3. **Generality:** Greater weight should be given to algorithms that apply generally, i.e., that are not restricted to specific regions or times. However, the importance of the algorithm may override this criterion even if it is regionally or temporally specific. The decision on generality should be made by the HQ Program Scientist, the SeaWiFS Project Scientist, and the Science Team.
4. **Accuracy:** The ability of the algorithm to perform as stated should be tested by independent confirmation. This function resides with the SeaWiFS Calibration

and Validation Leader or designate, and should involve comparisons with *in situ* observations.

5. *Compatibility*: The algorithm must be able to perform to expected standards within the operational SeaWiFS data system. Ideally required modifications should present no constraint. This decision will be made by the Data System Manager after detailed consideration of the algorithm.
6. *Resources*: If implementation of the algorithm requires substantial upgrading of the data system (either hardware or software), then the Data System Manager will provide cost and manpower requirements. This information will be presented to the SeaWiFS Project Manager to request the required resources.
7. *Approval*: Similarly, if archive and distribution functions of the DAAC are significantly impacted, the responsible DAAC Manager must provide cost and manpower requirement estimates, and an implementation schedule, and the approval of the DAAC User Working Group (UWG) should be obtained. The Project Scientist will be responsible for coordinating this approval.

W. Esaias December 12, 1991, rev. January 14 and February 22, 1993.

## Appendix C

### File Naming and Format Conventions for *In Situ* Data

Every file starts with a one-letter group code followed by a seven-letter numeric prefix, a period, and a three-letter suffix or extension. The group code describes who took the data, the prefix describes when the data in the file was collected, and the suffix provides a unique extension that should indicate the type of data in the file. A complete file name is as follows: GYYDDHH.EEE where, G is the one-letter group code, YY is the decadal year, DDD is the sequential day of the year, HH is the (starting) GMT hour of the day, and EEE is the file extension. Possible group codes are M for the MOCE group (perhaps N for the Navy group and others could be added, like, B for the BBOP group, and C for the CalCoFI group). In this schema the smallest collection interval is one hour. In the MOCE group this is not a problem, but it might be for others.

NOTE: This naming convention is motivated by the desire to use something that will work on every computer system the MOCE team is using in the field (Macintosh, IBM PC, VAX, NeXT, and HP). Consequently, the ensuing approach is driven by the most restrictive operating system.

The MOCE group currently divides the EEE field into an FFT field, where, FF is the file type, and T is the data type. The possible file types currently in use are OH and AV. OH is one hertz data, which is the nominal raw data, and AV is averaged data. The averaging interval for the latter can be discerned from the time stamps in the data file. The possible data types are: W for wind speed and direction, F for fluorescence, T for transmittance, B for barometric (air) pressure, R for relative air humidity and air temperature, and P for position information derived from the GPS receiver.

Cast or profile data has a slightly different naming convention: GNNNPQQQ.EEE where, G is the group identifier, NNN is the cruise

number, P is the profile code (U is for upcast, D is for downcast, and P is for a complete profile), QQQ is the sequential profile number, and EEE is the file extension.

Cruise specific files (e.g., master logs) are archived according to the group and cruise name they document: GCCCCNNN.EEE where, G is the group identifier, CCCC is a four-letter cruise name abbreviation, NNN is the cruise number, and EEE is the file extension.

Each file is composed of a file header, which describes what is in each column, and a sequence of data entries. Each data entry starts with a sequential record number and is followed by a GMT time stamp and the column entries for the data identified in the header. The GMT time stamp is in one of the following formats:

YYYYDDHHMMSS.ss or YYYYDDHHMMSS:ss,

where, YYYY is the calendar year, DDD is the sequential day of the year, HH is the GMT hour of the day, MM is the minute of the hour, SS is the second of the minute, and ss is the hundredth or sixtieth second of the second. To distinguish the two, the hundredths entry uses a period while the sixtieths entry uses a colon.

### Data Format Conventions

The following format conventions are recommended for all *in situ* data collection efforts:

1. All files must be in ASCII format. In the words of D. Siegel, "data files must be readable and editable by humans, not just by machines." This should not be a point of debate—disk space is cheap.
2. The data should be in a tab-delimited spreadsheet format, that is, rows and columns with all column entries separated by a tab.
3. All files must be self-describing, that is, all columns should have headers indicating what is in each column and what the appropriate units are. In cases where rows need headers to present matrix information, they should also be self-describing.
4. All header information should be underscore filled, that is, underscores are used instead of blanks. This allows for easy parsing, since many text translation routines (inside and outside of COTS programs) replace tabs with blanks.
5. All entries should be time-stamped using the aforementioned GMT format. With proper master or position logging, time is all that is needed to determine where the data was taken spatially, so if position does not appear in the file, a second time and position file must also exist. (For more thoughts on master logging, see the discussion below.)
6. Position information should be recorded as signed decimal degrees, that is, -75.50 and not 75.30.0W.
7. All entries should start with a sequential sample number, so missing data or file corruption can be readily discerned. (In some cases this will not be immediately applicable, but usually some sort of sequencing can be applied so gaps can be detected.) If possible, it would be useful if the header information, or perhaps a documentation file (see below), included the number of samples in the file (to detect shorts).
8. Documentation files should be created that describe, where appropriate, the hardware used to collect the data, the various techniques used to reduce or process the data, any relevant calibration information, and

any other information the investigator knows would help interpret the data, either by itself or in conjunction with other likely data sets.

#### Master Logging

The MOCE Team has developed an electronic master log. It is written as a LabVIEW VI and runs on a Macintosh PowerBook, Portable, or what have you, and has a simple GUI. The user pushes buttons to record the starting or stopping of an instrument's deployment. There are also buttons to log track, leg, and station numbers, and there are buttons to add comments, edit entries, and insert new entries. Each new entry is automatically time and position stamped.

The advantage of this approach is all that is required for most logging is button pushing. The text for the log entry is created by the interface and any numbering for stations, casts, etc., is controlled internally. There is a hierarchy of understanding built in, so the interface knows, for example, that when a station is started the previous track must be stopped. (In our hierarchy tracks connect stations and legs are departures along tracks.)

The net result is a simple (and reasonably foolproof) logging system that produces an ASCII file with a consistent and unique vocabulary, which makes it ideal for relational data base control. We are in the final stages of finalizing our vocabulary and instrument logging characteristics, but some questions remain. For example, should the up and down parts of casts be logged separately? Should bottle soak times for CTD casts be logged?

We are considering a multiple log environment where the master log is a coarse description of what happened, and then finer scale logs for hydrographic, particle and pigment analysis, etc., describe their respective responsibilities in greater detail. This approach is appealing because the architecture of the current master log is easily modified to accommodate a new lexicon.

#### Example Master Log Data

```
EVENT_NO GMT_TIME_STAMP LATITUDE LONGITUDE LOG_ENTRY
6 1992254011214:23 36.7403 -121.8548 MER Cast 1 started.
7 1992254011222:11 36.7407 -121.8552 CTD Cast 2 started.
8 1992254011225:47 36.7402 -121.8556 MER Cast 1 stopped.
...
```

#### Example Barometric Data

```
SAMP_NO GMT_TIME_STAMP OH_PRESSURE_MBARS
1 1992249230527:03 1015.14
2 1992249230528:03 1014.97
3 1992249230529:22 1015.00
...
```

#### Questions and Answers from Previous Reviews

Q: Do you normally keep the underway system going when you arrive on station to record the variability on station?

A: Yes.

Q: I'm confused about: "the interface knows, for example, that when a station is started the previous track must be stopped." What does that mean?

A: In our schema, tracks connect stations and legs are departures or intervals along tracks. For example, while steaming along Track 1 from Station 1 to Station 2, the ship crosses the Gulf Stream and a warm core ring. It would be useful to name the Gulf Stream portion Leg 1 of Track 1 and the ring portion Leg 2 of Track 1, so this data could be easily identified. Our master logger is programmed so that when you start a station, the previous track is terminated before a new station number is assigned; and if you start a track (or leg), the previous station is stopped; etc.

Q: Wouldn't it be useful to have a platform identifier, so if a group is doing two things at once (like, buoy refurbishment and another cruise) they could be distinguished?

A: The group identifier can be used for this. Refurbishment cruises by the MOCE team could be the R group, for example.

Q: Where are the instrument identifiers, to provide traceability for calibration, etc.?

A: This information should appear in the documentation files (item 8 above in *Data Format Conventions*).

Q: What is a COTS program?

A: Commercial off-the-shelf, like, Lotus 1-2-3, Excel, Improv, etc.

Q: What is a LabVIEW VI?

A: LabVIEW is a data acquisition package developed by the company National Instruments. There are versions for the Mac, PC, and SUN (to name a few). A VI is a virtual instrument which is the software representation of a data acquisition module.

S. Hooker December 12, 1991, rev. January 14 and February 22, 1993.

## Appendix D

### Responses to the SeaWiFS Questionnaire

This appendix presents the responses to the SeaWiFS Questionnaire which was distributed before and during the meeting. It is organized by assigning a number to each respondent, and then applying that number to each numbered entry on the original questionnaire. Anytime a respondent declined to answer or indicated the question was not applicable, no response is given for that respondent. The responses are presented as submitted with very minor modifications to correct typographic or obvious clerical errors.

#### 1. Principal investigator:

- 1.1 Eileen Hofmann
- 1.2 John Walsh
- 1.3 James Mueller
- 1.4 Charles Trees
- 1.5 Shiming Xu
- 1.6 J. Ronald Zaneveld
- 1.7 Greg Mitchell
- 1.8 Kendall Carder
- 1.9 Frank Hoge
- 1.10 Marcel Wernand
- 1.11 Roland Doerffer
- 1.12 Kevin Arrigo
- 1.13 Curt Davis
- 1.14 William Balch
- 1.15 Mati Kahru
- 1.16 Hajime Fukushima
- 1.17 Dan Kamykowski
- 1.18 Motoaki Kishino
- 1.19 Neil Tindale
- 1.20 Boris Sturm
- 1.21 Satsuki Matsumura
- 1.22 Robert Arnone

- 1.23 Giancarlo Carrada
- 1.24 Charles Yentsch
- 1.25 Gennady Korotaev
- 1.26 Umit Unluata
- 1.27 Frank Shillington
- 1.28 Janet Campbell
- 1.29 David Halpern
- 1.30 Oleg Kopelevich
- 1.31 Mark Luther
- 1.32 Raymond Smith
- 1.33 Philip Slater
- 1.34 David Siegel
2. *E-mail mailbox, phone number, fax number, and change of address:*  
*All responses from this category have been incorporated into Appendix E.*
3. *GAC Data Requirements from GSFC:*
  - 3.3 NE Pacific (equator to pole, North American coast to 180° W); level-1a; all for mission duration.
  - 3.4 Arabian Sea; level-1; January–September, 1994.
  - 3.6 World; level-1; all (joint study with J. Mueller)
  - 3.7 Global; level-1–3.
  - 3.8  $L_W$ ,  $Q$ ,  $f$ -ratio for:
    - NE Pacific, level-1, monthly, cloud-free;
    - Gulf of Mexico, level-1, monthly, cloud-free;
    - Caribbean Sea, level-1, monthly, cloud-free; and
    - N. Atlantic, level-1, monthly, cloud-free.
  - 3.10 40–65° N, 0–25° W; level-3;  $K(490)$ , pigment concentration, fixed region, daily periods.
  - 3.12 Southern Ocean (Weddell Sea, Bellingshansen Sea, SE Indian Ocean); level-1 ocean color; October–March.
  - 3.13 Radiances, chlorophyll; Equatorial Pacific and Arabian Sea; daily time series.
  - 3.14 Arabian Sea and the Gulf of Maine; level-2 (individual channels) and level-3 (pigments).
  - 3.15 Baltic Sea; Azores Current area in the subtropical Atlantic (centered at 21° W, 32.5° N), during the spring bloom period of March–April
  - 3.16 NW Pacific; level-1; all bands; all data throughout the year.
  - 3.17 U.S. Atlantic coast and continental slope to Gulf Stream; level-1–3; Nov. 1993, May 1994.  
 Gulf of Mexico; level-1–3; June 1994.
  - 3.18 Japan Sea; level-1–2; all year (from January 1994).
  - 3.19 SW Asia, NW Africa, Galapagos Islands, Arabian Sea, Southern Ocean, Gulf of Alaska, Equatorial Pacific, Hawaii, Australia, New Zealand.
  - 3.20 NW Africa upwelling area.
  - 3.21 NW Pacific (20–60° N, 110–180° E); level-2–3; type: chlorophyll,  $L_W$ ,  $K$ ; each week (16 per year).
  - 3.22 Mediterranean, Arabian Sea, U.S. East Coast, all level-1b; Gulf of Mexico, level-3.
  - 3.23 Central Tyrrhenian Sea, Ionian Sea, Sicily Channel; levels-1–3; all geophysical parameters; at least 3 months per year during cruises.
  - 3.24 Western North Atlantic, Gulf of Calif., Indian Ocean, Caribbean.
  - 3.25 Tropical Atlantic ( $\pm 15^\circ$ ), the Black Sea; GAC level-1–2; all year.
  - 3.26 Black Sea and Eastern Mediterranean; level-1b; daily.
  - 3.27 20–70° S, 0–60° E.
  - 3.28 Level-3 daily, weekly, monthly (all standard products); North Atlantic (north of 20° S); for life of SeaWiFS mission.
  - 3.29 Arabian Sea; July 1994 to June 1996.
  - 3.30 Level-1 where sea-truth data are available (for algorithm development); level-3 world, monthly (for global ocean primary production assessment).
  - 3.31 30° S–28° N, 35–125° E; level-1–3; continuously; all standard data products.
  - 3.32 Area: California Current region and west coast of Antarctic Peninsula for level-2. Specifically, Monterey Bay, Santa Barbara Channel on west coast of U.S. and the area near Palmer station in the Antarctic. We will eventually want the gridded global level-3 data.  
 Time: Throughout the life of SeaWiFS.  
 Type: We essentially want both raw radiance values and derived products for these times and areas.
  - 3.34 Primarily Sargasso Sea for level-2 and will eventually want to look at global data at level-3 when it's mapped onto a latitude and longitude grid; throughout the time period of JGOFS time series work at Bermuda. *I'm a little unclear about how the radiance data is normalized in level-3. Can one easily go from  $L_W$  values to  $L_{WN}$ ? This is important for the IOP inversion scheme we're trying to use.*
4. *LAC/HRPT data requirements from GSFC:*
  - 4.1 Southeastern U.S. continental shelf.
  - 4.2 Gulf of Mexico, Caribbean Sea, and South Atlantic Bight.
  - 4.3 NE Pacific (15–40° N, North American coast to 130° W); level-0 or level-1a; as available.
  - 4.4 Arabian Sea; level-1; January–September 1994.
  - 4.8 Gulf of Mexico, level-1, seasonal,  $L_W$ ,  $Q$ ,  $f$ -ratio; NW Atlantic, level-1 seasonal; global cruise support (2 cruises maximum per year).
  - 4.9 Mid-Atlantic Bight (NY to Hatteras), Southern California Bight; during spring bloom and mid-winter; water-leaving radiances in all bands.
  - 4.10 51–58° N, 8° E–2° W (North Sea); level-1 and 2; calibrated radiances, level-1 reflectance, pigment concentration, chlorophyll,  $K(490)$ , radiances, fixed region, whole period.
  - 4.11 Will be received from European stations; level-1; North Sea and Baltic Sea (50–60° N, 5° W–30° E); March–October; cloud-free scenes.
  - 4.12 Southern Ocean (if available).
  - 4.14 Arabian Sea and Gulf of Maine, level-2–3.
  - 4.15 Baltic Sea (if available).
  - 4.16 None, provided we can get Japanese data from NASDA.
  - 4.17 U.S. Atlantic coast and continental slope to Gulf Stream; level-1–3; November 1993, May 1994.  
 Gulf of Mexico; level-1–3; June 1994.

- 4.18 Japan Sea near the NASDA Buoy Station; level-1; September 1993 to December 1993 (sensor cal/val period).
  - 4.20 Baltic, Tyrrhenian Sea, NW Africa (interest in other European sites); level-1.
  - 4.21 None (if HRPT station is permitted in Japan).
  - 4.22 East Coast of U.S., Gulf of Mexico, Arabian Sea, Mediterranean (1995) to support ship validation programs; level-1 products; would like HRPT available to send to ship while at sea.
  - 4.23 Central Tyrrhenian Sea, Ionian Sea, Sicily Channel; level-1-3; all geophysical parameters; at least 3 months per year during cruises.
  - 4.24 Support of Gulf of California cruises; Arabian Sea (to be planned); Caribbean (to be planned).
  - 4.25 Support of the North Atlantic cruise in 1994 (being planned).
  - 4.26 None, since we are aiming to get LAC/HRPT from our own ground station.
  - 4.27 Plan to collect LAC/HRPT data from Satellite Applications Centre (SAC), CSIR, South Africa.
  - 4.28 Level-1, level-2, and level-3? data; Gulf of Maine, Georges Bank, and Slope Waters SE of Georges Bank; all data products; daily.
  - 4.29 Arabian Sea; July 1994 to June 1996.
  - 4.30 Western part of Mediterranean (frontal zones); NW African coast (upwelling region); Western part of North Atlantic subpolar front; level-2; 10-15 day periods in different seasons; cloud-free scenes.
  - 4.31 0-28° N, 45-80° E; level-1-3; continuously; all standard data products.
  - 4.32 Areas, times and types as above; *however, it is my understanding that GSFC will not provide LAC data for the U.S. west coast or for the Antarctic Peninsula.*
  - 4.33 Edwards Air Force Base (EAFB) and Lake Tahoe; level-1b (radiometrically corrected but not resampled); digital counts; no requirement for real-time data, *but need to know within 24 hours if the image acquisition was successful.*
  - 4.34 It is my understanding that the time series people (Knap, Michaels, and Hansell) desire LAC coincident with their observations for their own purposes. I am not funded to do this work. They would like data in near-real time for sediment trap buoy recovery, etc. *I think they should be contacted directly (a.knap or a.michaels). I do not envision needing any for myself at this time.*
5. Non-GSFC HRPT data requirements:
- 5.3 Gulf of California, NE Pacific (15-40° N, North American coast to 130° W); HRPT level-0; all for mission duration.
  - 5.7 Level-1; daily; U.S. west coast and Mexico with SIO, SeaSpace, or Ocean Imaging as a data source and the Antarctic Peninsula with NSF as a data source.
  - 5.8 Global cruise support (a maximum of 2 cruises per year).
  - 5.10 Dundee (UK) as a data source.
  - 5.11 Receiving stations are DLR, Oberpfaffenhofen, BSH, Hamburg, Dundee Scotland, GKSS NOAA AVHRR station (to be modified to receive SeaWiFS data); data from China for a joint project with China (Second Institute of Oceanography, Hangzhou, Dr. Pan Delu).
  - 5.13 Radiances, chlorophyll; west coast of U.S., Hawaii including JGOFS time series station; daily time series.
  - 5.15 Baltic Sea.
  - 5.16 Japan Fisheries Agency (NASDA); Japan area; level-1; all bands; selected data (20% suggested); throughout the year.
  - 5.18 Japan Sea; from National Fisheries Research Institute (NASDA); level-1-2; all year (from January 1994).
  - 5.19 Arabian Sea, assuming there is a NASA approved HRPT station in the vicinity.
  - 5.21 HRPT receiving station will be set onto N.R. Institute of Fish. Science (Japan); area is Japan Sea and NW Pacific; level-1-3; chlorophyll,  $L_w$ ,  $K$ ; every time.
  - 5.22 At Stennis Space Center we plan to receive all Gulf of Mexico and Caribbean Sea data from our HRPT collection site. We will process all to level-3 at 1 km resolution. *Is HRPT available for the Arabian Sea?*
  - 5.23 ESA; Central Tyrrhenian Sea, Ionian Sea, Sicily Channel; level-1-3; all geophysical parameters.
  - 5.24 Full data for Gulf of California, Arabian Sea, Caribbean.
  - 5.25 Black Sea, HRPT in Caribbean; all bands; selected data for first year, full data in future.
  - 5.27 From the CSIR Satellite Applications Centre, Pretoria, South Africa; 20-40° S, 0-40° E; level-0-2; as often as possible (once per week?).
  - 5.31 0-28° N, 45-80° E; level-1-3; Arabian Sea region ground stations; types: SeaWiFS, AVHRR (SST, SeaWiFS SDP).
  - 5.32 We want a NASA license for Palmer Station in the Antarctic and there is some chance we will have a TeraScan system in Santa Barbara. These details are not yet worked out.
6. SeaWiFS ancillary data requirements:
- 6.3 Will use all available from NE Pacific (15-40° N, North American coast to 130° W); minimum is winds, pressure, and ozone to support independent processing.
  - 6.7 All standard ancillary fields required to process level-1 data obtained.
  - 6.8 Pressure, winds, and ozone.
  - 6.9 NASA Airborne Oceanographic Lidar (AOL) active-passive data; ship/extracted pigments: chlorophyll, phycoerythrin; other surface samples: 0.45  $\mu$ m filtered water for DOM and DOC analysis.
  - 6.11 Pressure, wind, ozone, organized for all European sites through ESA (planned Octopus project).
  - 6.12 Pressure, winds, ozone, and cloud cover.
  - 6.14 Winds and sea surface elevation.
  - 6.15 Pressure, wind, and ozone fields from the Baltic Sea area.
  - 6.16 Pressure, winds, and ozone (global).
  - 6.17 Pressure, winds, ozone, etc.; require information on what is available.
  - 6.18 Pressure, winds, ozone, and solar radiation.
  - 6.19 Dust concentrations in the marine boundary layer, air temperature, and wind speed and direction.
  - 6.20 Pressure, ozone, and wind.
  - 6.21 Winds and sea surface temperature.
  - 6.22 We have a direct line to FNOG for supporting meteorological data. *Are field data available for the Gulf of*



*Mexico in near-real time? Who is collecting it and placing it into a database? There are platforms in the Gulf with these data streams that can be obtained and incorporated into SeaWiFS processing and we would like to get it.*

- 6.23 Winds.
- 6.24 Winds.
- 6.25 Tropical Atlantic, Black Sea; pressure, wind, sea surface temperature, and sea level.
- 6.26 All ancillary data required to process level-1 LAC data.
- 6.28 Possibly winds (TBD).
- 6.29 None, but I need a description of the algorithm used to produce the phytoplankton pigment concentration.
- 6.30 All available data concerning level-1 data: pressure, winds, ozone, and sea surface temperature.
- 6.31 0–28° N, 45–80° E; surface winds, atmospheric ozone concentration, pressure, surface irradiance (400–700 nm).
- 6.32 Sea level air pressure and wind speed might end up being very useful for our proposed work. We are also interested in obtaining ozone data if these are available.
- 6.33 We will be collecting all ancillary data needed.
- 6.34 Sea level air pressure and wind speed might end up being very handy for our proposed work.
- 7. *In situ data requirements from GSFC:*
  - 7.3 TBD, proposed projects will acquire necessary *in situ* data internally, but we'll use any other data that is relevant.
  - 7.7 Access to calibration mooring data; access to cal/val optical, pigments, and production database.
  - 7.8 Pigments, chlorophyll *a* (HPLC),  $a_p(\lambda)$ ,  $a_g(\lambda)$ ,  $K_d(\lambda)$ ,  $R_{rs}(\lambda)$ , DOC,  $L_u(\lambda)$  as available.
  - 7.9 NASA AOL active-passive data; ship/extracted pigments: chlorophyll, phycoerythrin; other surface samples: 0.45  $\mu$ m filtered water for DOM and DOC analysis.
  - 7.12 Southern Ocean pigments and bio-optics.
  - 7.14 Primary production, pigments, light, and nutrients.
  - 7.17 Require information on what is available.
  - 7.19 Aerosol optical depth and radiance.
  - 7.22 We will obtain much of our own *in situ* data, but would like GSFC to archive other Gulf of Mexico *in situ* data if they could. We will provide GSFC all ship data collected. Can GSFC obtain NDBO buoy data in the Gulf of Mexico?
  - 7.24  $I_0$ ,  $L_u$ ,  $K$ , and chlorophyll.
  - 7.30 Sea truth measurement data concerning level-1: atmospheric and oceanic optical characteristics, pigments, suspended matter, primary productivity, etc.
  - 7.31 Incident spectral irradiance, water-leaving radiance, attenuation coefficients (up, down), fluorescence profiles, wind velocity, temperature and salinity profiles, phytoplankton pigments and CDOM concentration, spectral attenuation, absorption and backscattering coefficients, spectral volume scattering function, coccolith concentrations, primary productivity, new production, and total DOC.
  - 7.33 We will be collecting all ancillary data needed.
- 8. *Data you will deliver to the SeaWiFS project:*
  - 8.3 Validation data (radiometry, optics, and pigments) as per the CHORS support contract with the SeaWiFS Project; Gulf of California same as above plus P vs. I,  $E_s(\lambda)$  time series and fluorescence time series from mooring off Guaymas, and hydrography.
  - 8.4 Nine months after each cruise we will provide a data report with data stored on floppy disks.
  - 8.6 Spectral absorption coefficient, spectral beam attenuation coefficient, spectral backscattering coefficient, all as a function of depth; timing and location to be determined by funding levels.
  - 8.7 From quarterly CalCoFI cruises (Jan., Apr., Jul., and Sep. of each year):
    - $L_u$ , 13 spectral bands at 400–700 nm;
    - $E_d$ , 13 spectral bands primary production,  $P_{max}$ ;
    - $K$   $E_d$ , 13 spectral bands hydrography (CTD, nutrients, etc.); and
    - $L_W$ , 13 spectral bands delivery within 12 months of collection.
  - 8.10 Schedule: SeaWiFS operational period (starting 1994); North Sea; Types: groundtruth optical data,  $C(530)$ ,  $C(670)$ ,  $C(\text{spectral}, 22 \text{ bands})$ ,  $K_{up}(\text{spectral}, 22 \text{ bands})$ , upwelling radiance (100 bands, 380–780 nm), shipborne downwelling radiance (100 bands, 380–780 nm), shipborne reflectance (spectral, 122 bands, 380–720 nm), airborne fluorometry (aquatrack), Seabird CTD.
  - 8.11 Sea Truth Data: concentrations of phytoplankton pigments, suspended matter, yellow substance, *in situ* optical measurements, measurements of specific optical properties of water constituents in the North Sea and the Baltic Sea.
  - 8.12 Proposed level-2 and level-3 pigment fields for the Southern Ocean; gridded pressure, wind, and ozone fields for the Southern Ocean; 3-D model results—circulation and primary production.
  - 8.13 Calibrated, corrected MER data, with transmissometer, CTD, fluorometer data; surface reflectance data; approximately 6 months after each cruise; U.S. west coast, Arabian Sea.
  - 8.14 Primary production algorithms.
  - 8.16 Possibility: data collected by a NASDA supported mooring in the Japan Sea (M. Kishino may comment on his questionnaire).
  - 8.18 NASDA Japan Sea Buoy Data; parameters: surface incident spectral irradiance, downward spectral irradiance depth of 1.5 m and 6.5 m, upward spectral radiance at depth of 1.5 m and 6.5 m, spectral range of 400–800 nm, spectral resolution of 2 nm, fluorescence at a depth of 1 m, temperature at a depth of 1 m, wind speed and direction, surface pressure, position; time and position: test operation—August 1993 to December 1993, 132° E, 35° 40' N; operation—from April 1994, Japan Sea Yamato Bank.
  - 8.19 Aerosol concentration and type in the marine boundary layer.
  - 8.20 Results of algorithm development (semestral).
  - 8.21 Chlorophyll, phaeopigment, sea surface temperature, productivity measured by  $^{13}\text{C}$ , nutrients, underwater spectral irradiance, field fluorescence data; area is around Japan (20–60° N, 120–160° E) and Antarctic sea; 4 research vessels have 2–3 cruises (10–20 days each) in a year.
  - 8.22 1) Ship optical data within 6 months, and 2) Data from Gulf of Mexico, Arabian Sea, U.S. East Coast, Mediter-

anean Sea, Coastal areas (Mississippi delta, Chesapeake Bay); data will be in a standard format; standard optics data, CTD, and other data types too numerous to list; conducting a cruise in April 1993 to establish the data type and format; data availability are dependent on ship availability.

- 8.24 Special optical MES, particle numbers and size.
- 8.25 Hydrology profiles, bio-optical measurements from 2 cruises per year, atmospheric optical depth measurements (1–2 months for first year, during entire year in future).
- 8.26 CTD, fluorometer, upwelling and downwelling radiances, transmissometer; some 6–9 months after cruise; on floppies.
- 8.28 Winter nitrate, depth of nitracline in late summer, new production in North Atlantic for 1994, 1995 at level-3 spatial scale; 3 gridded maps per year.
- 8.29 Publications, including atlases.
- 8.30 All optical and biological data of our field studies.
- 8.31 Ocean circulation variables from model (velocity, temperature, mixed layer depth, and thermocline depth), chlorophyll, nutrient fields, water column production, organic carbon (all from a coupled physical and biological model).
- 8.32 Our bio-optical mooring data will ultimately be available to the SeaWiFS project. Timing for this effort is dependent upon logistics and collaborative research efforts related to our mooring deployment and travel to and from the Antarctic.
- 8.33 Calibration data two months after image acquisition at EAFB, probably in March, 1994. Calibration data two months after image acquisition at Lake Tahoe, probably in September 1994.
- 8.34 We will deliver bio-optical profile data from BBOP on a next day basis. One cast per day will be selected and processed at the Bermuda BioStation. A chlorophyll *a* profile (fluorometric method) will also be provided at that time. This should make up about 50–60 days of data each year. At a later date, the SeaWiFS project is welcome to take any of our (or other BATS-core data) from our anonymous FTP account.

#### 9. Field studies:

- 9.3 Productivity in the Gulf of California; correlations with diatom deposition in sediment varves off Guaymas, and ENSO-related variables.
- 9.4 Arabian Sea; winter and summer 1994; upwelling and downwelling irradiance; upwelling radiance; beam *c* measurements; fluorescence; particulate and DOM absorptions.
- 9.6 Proposed participation in the SDSU/CICESE study in the Gulf of California and the OLIPAC cruise.
- 9.7 Quarterly CalCoFI cruises; Pt. Conception San Diego to 1,000 km offshore; may have opportunity for one additional investigator on some cruises.
- 9.10 North Sea; 1993 (April, July, August, November) one week cruises near coast up to 30 miles off coast; 1994 and later unknown; bio-geo parameters: pigments, chlorophyll concentration and species, total suspended matter concentration and camera observations of flocs in the North Sea; room for up to 2 other investigators.
- 9.11 1993: German Bight, North Sea, April 26 to May 9 and September 6–11.
- 9.13 Monterey Bay and Southern California Bight; November 1993, July 1994—no extra room; Arabian Sea JGOFS plankton cruises 1994–95.
- 9.14 NSF Arabian Sea (1994–95); possibility of room for NASA PIs.
- 9.15 Mostly on-line measurements from several ferry lines across the Baltic Sea.
- 9.17 May 14–19, 1992; Slope Water north of Cape Hatteras; MER 2040, HPLC <sup>14</sup>C-SIS. June 23–28, 1992; Gulf of Mexico Slope Water off Tampa, Florida; MER 2040, HPLC <sup>14</sup>C-SIS.
- 9.18 Cruises for buoy—several from August to December 1993; small ship (no room).
- 9.19 Galapagos Islands in the fall of 1993; Arabian Sea from 1994–1995; Southern Ocean from 1995–1996?
- 9.20 Bio-optical measurements in collaboration with local institutes (Naples, Baltic) are planned for 1993 and 1994.
- 9.21 Japanese ship deployments (other investigators are welcome):
 

Ship Name	Area	Days	Measurement
<i>Shunnyoumaru</i>	Oyashio	2×20	nutrients, pigments, $E_u$ , $E_d$ , $L_w$ , quanta, wave, <sup>13</sup> C
<i>Soyoumaru</i>	Kuroshio	2×25	nutrients, pigments, <sup>13</sup> C
<i>Wakatakamaru</i>	Oyashio	3×15	nutrients, pigments
<i>Mizuohomaru</i>	Japan Sea	3×9	nutrients, pigments, $E_u$ , $E_d$ , $L_w$ , quanta
<i>Kaiyoumaru</i>	Pacific	50	for 1994
<i>Kaiyoumaru</i>	Antarctic	150	for 1994–95
- 9.22 1) April 1993 in the Gulf of Mexico, ship is packed; 2) 1994 in the Mediterranean, looking for some support, but don't know if all investigators can go. We have several cruises planned per year. We are hoping to establish a team with USF, SDSU as a minimum; others include Oregon State. The cruises are dependent on ship time availability which is determined at the beginning of the fiscal year.
- 9.23 Spring, Summer, Fall 1994 and 1995; surface mapping of photosynthetic activity—downwelling and upwelling irradiance (Biospherical); fluorescence and photosynthetic activity profiles; CTD; HPLC pigments; room for other investigators will depend on what ship will be available.
- 9.25 Black Sea, 2 cruises/year; North Atlantic, 1 cruise (no details yet).
- 9.26 Black Sea in April 1993, within the limits of Turkish EEZ; up to 2 scientists can be accommodated for later cruises; next one will be summer 1993.
- 9.27 Regular SFRI cruises to shelf region of Agulhas Bank (4–5 p.a.); *in situ* fluorescence, chlorophyll *a*, temperature, salinity, nutrients, <sup>15</sup>N uptake; Southern Ocean in South African sector down to Antarctic (0–30° E) approximately 3 times per year; room available.
- 9.28 TBD (chlorophyll, nutrients, CTD, etc.); I am hoping to provide SeaWiFS data to support field work in the Gulf of Maine; approximately 4 cruises per year.
- 9.31 ONR/JGOFS/WOCE Arabian Sea Process Study October 1994 to October 1996; all physical, biological, and geochemical variables; from moorings, ships, aircraft; still room for other investigators.
- 9.32 In collaboration with Francisco Chavez at MBARI, we

- have Bio-Optical Moored Systems (BOMS) at several depths on a mooring in Monterey Bay. We expect this mooring, and associated biological sampling, to extend throughout the lifetime of SeaWiFS. In collaboration with the Palmer LTER (Long-Range Ecological Research) program, we are obtaining periodic bio-optical data in the vicinity of Palmer Station on the Antarctic Peninsula. This program is expected to continue beyond the lifetime of SeaWiFS.
- 9.33 The field measurements will be made at EAFB and Lake Tahoe. They will consist of spectral reflectance, spectral optical depth, BRDF, columnar water vapor and ozone amount. In addition, at Lake Tahoe sun glint measurements will be made from a light aircraft and *in situ* measurements of chlorophyll *a* and colored dissolved organic matter will be made by the USF group. Other investigators welcome.
- 9.34 In collaboration with the Bermuda Atlantic Time Series (BATS) program, we will make bio-optical profile observations. Variables include  $E_d$ ,  $L_u$ ,  $a$ , and  $c$  (all spectral) as well as the suite of CTD variables. Between our recently funded *in situ* measurements and the BATS core program almost everything you guys care about (HPLC,  $a_p$ ,  $a_{dis}$ , particle size spectra, etc.) will be measured.
10. *Real-time data requirements for field studies:*
- 10.3 Local HRPT coverage for Gulf of California, Mexican Coast, California Coast.
- 10.4 Jim Aiken will make these requirements.
- 10.6 Will need the support of SDSU for apparent optical properties and biochemical parameters; CICESE for CTD and moorings; for schedule see the SDSU proposal.
- 10.14 Arabian Sea 1994 and 1995—specifically need pigment and 550 nm band.
- 10.16 Northeastern part of the Japan Area in June.
- 10.19 Galapagos Islands in fall 1993; Arabian Sea in 1994–95; Southern Ocean in 1995–96?
- 10.21 Level-2; chlorophyll,  $K$ ; during research cruises listed earlier.
- 10.22 Mediterranean, 1994; East Coast, spring 1994; Arabian Sea, 1995; need onboard taped and then processed to level-2 at 1 km resolution; for ship stations coordination real time SeaWiFS at 1 km resolution, level-1 or level-2, is needed for areas listed previously; we can only receive Gulf of Mexico region and will need support for other areas.
- 10.23 Level-2 data during the cruises.
- 10.24 Gulf of California and Arabian Sea.
- 10.25 For the Black Sea cruises; twice per year; on the HRPT station in Crisea.
- 10.26 Real-time SeaWiFS data during bio-optical cruises; support is required for our HRPT ground station license approval.
- 10.27 Real-time data through SAC?
- 10.30 Level-1 SeaWiFS and AVHRR data during research cruises.
- 10.31 Real-time data for Arabian Sea ( $0-28^\circ$ ,  $45-80^\circ$ ) to provide support for field program; plan to distribute products in near-real time to all interested investigators.
- 10.32 We have no strict requirement for real-time LAC data, but a strong requirement for *delayed* LAC data in our two primary areas of interest (see question 4 above).
- 10.33 No real-time imagery data needed. Need verification of data collection within 24 hours.
11. *Plans for calibration of in situ instruments:*
- 11.3 As per CHORS contract with the Project.
- 11.4 Calibration both pre- and post-cruise for a MER 1032 at CHORS facility.
- 11.6 Instruments will be calibrated in the laboratory prior to each cruise.
- 11.7 Biospherical instruments on CHORS calibration of MER 2040 and MER 1012; calibration round-robin is essential!
- 11.10 Sea-going radiometers calibrated in laboratory at Neth. Inst. for Sea Research.
- 11.11 1993 field studies will be used to calibrate and test new underwater spectrometer.
- 11.13 Calibration of MER 1048 and personal spectrometer II by J. Mueller et al at CHORS, before and after each major experiment (2–3 times/year).
- 11.17 Recommendations of Science Team.
- 11.18 Radiometers of buoy and sea-going radiometers: NBS Standard Irradiance Lamp; these calibrations will be carried out at M. Kishino's Lab.
- 11.19 In our full proposal we have requested funds for one calibration per year of a radiometer.
- 11.21 Using standard lamp in laboratory.
- 11.22 Radiometers have been purchased and some have come in; plan to be part of the SDSU round-robin; these will include transmissometers, absorption, radiometers, and spectral irradiance devices.
- 11.25 In laboratory, before cruises.
- 11.26 LICOR radiometer will be calibrated with its own calibrator before each cruise.
- 11.27 Intend to acquire Biospherical radiometer for use on Aguillas Bank and Southern Ocean.
- 11.30 In laboratory and in the Institute of the Optical-Physical Measurements (Moscow); it's desirable to have unique secondary standard units (standard lamps, calibration plaque or small integrating sphere) and instructions.
- 11.31 Hope to calibrate with investigators in Arabian Sea Process Study, but no definite plans.
- 11.32 We (CSL/CRSEO/UCMBO at UCSB) are part of the SeaWiFS round-robin calibration effort. We have a long history of careful optical calibration of sea-going instruments and plan to continue this tradition. We are presently doing periodic optical calibrations of both profiling (BOPS-II and OFFI) and moored (BOMS) instruments.
- 11.33 Calibration of instruments will be conducted at U. of Arizona and USF.
- 11.34 We (the UCSB lab) are part of the SeaWiFS round-robin calibration effort. We are presently doing optical calibrations quarterly.
12. *Contributions to your investigation from other funding sources:*
- 12.3 CICESE (Mexico) for ship time and collaboration.
- 12.4 Ship time from the U.K.
- 12.6 I hope to participate in the Gulf of California Remote Sensing Experiment. Ship time will be contributed by the Mexican Government. Instrumentation development

has been funded primarily by NSF calibration procedures supported by ONR.

- 12.7 State of California for 35 ship-days/year; NOAA for 35 ship-days/year.
- 12.10 Part of instrumentation is funded by Tidal Water Division Rijkswaterstat. Ph.D. student financially supported by Netherlands Board for Remote Sensing.
- 12.11 Development and application test of a new underwater spectrometer system through cooperation with University College Dublin which is funded by European Community MAST I and II.  
Coastal Zone Research Project KUSTOS (as contribution to IGBP core project LOICZ), starting 1994 and in cooperation with University of Hamburg which is funded by Minister for Research and Technology Germany (BMFT).  
Sylter Wattenmeer Austauschprozesse (SWAP) until end of 1995, in cooperation with Anstalt Helgoland and University of Kiel.  
Ship time, aircraft operation, and data evaluation will be financed mainly through R&D budget of GKSS and DLR.
- 12.13 Arabian Sea Cruises proposed in NASA RTOP renewal.
- 12.15 Funding from Sweden and Finland.
- 12.16 The Japan mooring (NASDA).
- 12.17 NSF and ONR for ship time and computers.
- 12.19 ONR for ship time and field costs for the Southern Ocean and some support in the Arabian Sea and Galapagos experiments.
- 12.20 Funding only by CEC/JRC.
- 12.21 All funding comes from other sources outside of SeaWiFS.
- 12.22 Entire effort comes from the Navy; Navy OP 096 for data collection at SSC and algorithm development; ONR and NRL for Basic research in Ocean Color Phenomenon; Office of Naval Technology for Optical Database in coastal Gulf of Mexico.
- 12.23 Italian Space Agency (ASI); Italian Research Council (CRN).
- 12.26 NATO, Turkish Scientific Research Council.
- 12.27 South African Benguela Ecology Programme (BEP) sponsored by FRD; South African Antarctic Res. Program sponsored by DEA; Sea Fisheries Res. Institute sponsored by DEA.
- 12.28 "Mitchell Bill" funding for Gulf of Maine—funding is to other investigators, I will supply SeaWiFS data.
- 12.29 NASA SR&T funds.
- 12.30 Russian Academy of Sciences.
- 12.31 ONR and NSF are funding portions of model development and real-time model output distribution.
- 12.32 NSF funds the Palmer LRER program as well as our, unrelated, Ice Colors 93 program. NASA is funding our mooring effort in Monterey Bay and contributing to our instrument and calibration efforts for the Antarctic sampling.
- 12.33 Other funding sources for this work: EOS contracts at U. of Arizona and USF.
- 12.34 NSF funds the BBOP program for measuring AOPs and modeling light penetration and primary production at

BATS. NSF also funds the ship time via the BATS program. We receive NASA support for participation in the calibration round-robin (via the SeaWiFS calibration and validation effort) and have recently received SeaWiFS funding to make detailed IOP observations and to develop an IOP inversion model for color spectra.

13. *Computer model and operating system you are using:*
  - 13.1 SUN workstations (SPARC); UNIX-based systems.
  - 13.2 DEC micro-VAX; VMS.
  - 13.3 SGI [Crimson, Indigo (R4000)/Indigo (R3000)]; UNIX.
  - 13.4 IBM 386.
  - 13.6 Macintosh IICx; Mac 7.0.1.
  - 13.7 IBM 386/486; MS-DOS/Windows. SGI Indigo; UNIX.
  - 13.10 PC 386 and 486; MS-DOS. SUN workstations; UNIX.
  - 13.11 SUN SPARC 10, SUN MP 630 server, IBM 6000; all UNIX.
  - 13.12 Macintosh; Mac/OS. SUN; UNIX.
  - 13.13 IRIS Indigo; IRIX 4.0.5.F. SUN SPARC II; SUN OS.
  - 13.15 A network of SUN SPARCstations 1+ with UNIX, linked via NFS with a series of 486 PCs with MS Windows.
  - 13.16 MicroVAX 3400 (VMS and Miami DSP); DEC station 5000/200 (ULTRIX), SUN SPARC 2 (SUN-OS), Macintosh IIvx (System 7), PS/AT (PC SEAPAK).
  - 13.17 SWAN 486, DEC Station 5000.
  - 13.18 SUN SPARCstation/SUN OS 4.1.2.
  - 13.19 VAX/VMS, SGI/UNIX, PC/MS-DOS.
  - 13.20 VAX 4000-300 (VMS), SUN Network (UNIX), PC + Transputerboard (DOS).
  - 13.21 SUN-4; Tela scan system.
  - 13.22 SGI 4D35, SGI Indigo, SGI Crimson, SUN, PCs.
  - 13.23 MicroVAX, PC 486.
  - 13.25 PC 386 and 486; MS-DOS/Windows.
  - 13.26 Compaq 386/33; DOS.
  - 13.27 IBM 486 with MUPAT monitor; SEAPAK software.
  - 13.28 MicroVAX II; UNIX Workstation in future (either SUN, SGI, or DEC).
  - 13.29 SUN; UNIX.
  - 13.30 PC AT 286/287.
  - 13.31 SGI IRIS 4D/310 VGX; IRIX; Cray YMP (both UNIX platforms).
  - 13.32 CRSEO is a heterogeneous environment of DECstations (including Alpha platforms), SUN SPARCstations, SGI IRIS's and a variety of Macintosh computers. We primarily run in UNIX and use X-Windows. Our sea-going equipment currently makes use of DEC PCs with basic the link to instruments.
  - 13.33 SUN SPARCstation network with UNIX-based SUN OS (4.1.2 or 4.1.3).
  - 13.34 We have a heterogeneous environment of DECstations (including Alpha platforms), SUN SPARCstations, and SGI IRISs. We run in UNIX and use X-Windows.
14. *Preferred data distribution vehicle:*
  - 14.1 Network or 8 mm.
  - 14.3 CD-ROM or 4 mm.
  - 14.4 9-track.
  - 14.6 8 mm.

- 14.7 Probably 8 mm; network.
- 14.10 8 mm, Sony metal particle video 8 cartridge (up to 2279 MB).
- 14.11 8 mm or 4 mm, 9-track.
- 14.12 8 mm, 4 mm, or Network.
- 14.13 4 mm or network.
- 14.14 8 mm.
- 14.15 Network, 9-track; hopefully 8 mm or 4 mm system in the future.
- 14.16 8 mm.
- 14.17 8 mm, network.
- 14.18 8 mm.
- 14.19 Network.
- 14.20 8 mm (low density), 9-track (6250 bpi).
- 14.21 4 mm, 8 mm.
- 14.22 Network first, then 8 mm.
- 14.23 8 mm.
- 14.25 8 mm, CD-ROM.
- 14.26 9-track tapes (for the time being).
- 14.27 Network.
- 14.28 4 mm (now) or 9-track; network (future).
- 14.29 8 mm (need to check with my computer programmer).
- 14.30 Network or streamer cassettes "Jumbo" 120 MB.
- 14.31 8 mm or network (internet); 4 mm in future.
- 14.32 Network FTP or 8 mm are fine.
- 14.33 9-track 6250 bpi 1/2" CCT, 8 mm, or network.
- 14.34 Network FTP or 8 mm are our favorites.

NOTE: It is assumed references to 8 mm are for EXABYTE tape and references to 4 mm are for DAT.

15. Preferred data distribution frequency:

- 15.1 On request.
- 15.3 As available.
- 15.4 On request.
- 15.6 On request.
- 15.7 Monthly.
- 15.10 Once a month and on request.
- 15.11 SeaWiFS data and ancillary data (pressure, wind, and ozone) monthly or quarterly.
- 15.12 On request.
- 15.13 As available.
- 15.14 On request.
- 15.15 As available.
- 15.16 Monthly.
- 15.17 On request.
- 15.18 Weekly.
- 15.19 As available.
- 15.20 On request.
- 15.21 Monthly, on request.
- 15.22 On request.
- 15.23 Monthly except during cruises.
- 15.25 On request.
- 15.26 Monthly.

- 15.27 Weekly or as available.
- 15.28 GAC level-3 weekly, LAC on request.
- 15.29 Weekly.
- 15.30 Monthly and on request.
- 15.31 As available.
- 15.32 Monthly data is adequate.
- 15.33 On request.
- 15.34 I think monthly will easily suffice for our needs.

16. Miscellaneous items submitted by respondents:

- 16.5 I will represent NCSA at the meeting and would like to know the SST requirements from HDF in terms of speed, size of data sets, number of data sets, and functions and operations supplied by HDF.
- 16.10 Availability of image processing software (used or public domain).
- 16.11 ESA and Joint Research Centre Ispra (Commission of the European Community) are preparing a support structure for European users of SeaWiFS (working name is Octopus) through which data receiving, archiving, and distribution will be organized. It will follow NASA structure as closely as possible. I hope it will work. I also suggest a subworking group for Case II water researchers.
- 16.22 Many of the questions on this sheet can't be answered concretely so take what I have given here as my best guess. Much of the efforts desired require a timely exchange with GSFC. We need the following: 1) March '93, software for level-0-2; 2) June '93, first software module on atmospheric correction, 3) May '93, what are GSFC's plans for providing software for processing SeaWiFS (DSP, IDL, SEAPAK, etc.)? How do we access the GSFC database (June '93)? Does GSFC want all level-1 and level-3 data we obtain at Stennis?
- 16.32 There needs to be at least some minimum coordinated effort with respect to the cataloging of the availability LAC data from diverse sites. At least set up a central location where information about SeaWiFS LAC data could be submitted in a standard format.

## Appendix E

### Attendees to the First SeaWiFS Science Team Meeting

The attendees to the meeting are presented alphabetically. Science Team members who did not attend the meeting are shown in *slanted* type face and are included for completeness.

Mark Abbott	<i>SeaWiFS Science Team</i>
OSU/College of Ocean.	<i>MODIS Science Team</i>
Oceanography Admin. Bldg. 104	
Corvallis, OR 97331-5503	
Voice: 503-737-4045	
Fax: 503-737-2064	
Omnet: m.abbott	
Internet: mark@speedy.oce.orst.edu	

James Acker
NASA/STX/Code 971
Greenbelt, MD 20771
Voice: 301-286-1444
Fax: 301-286-2717
Omnet: j.acker
Internet: jgacker@neptune.gsfc.nasa.gov

# Proceedings of the First SeaWiFS Science Team Meeting

James Aiken  
Plymouth Marine Laboratory  
Prospect Place  
West Hoe  
Plymouth, PL1 3DH  
UNITED KINGDOM  
Voice: 44-752-222772  
Fax: 44-752-670637  
Omnet: pml.uk  
Internet: ja@uk.ac.npm.ia

*SeaWiFS Science Team*

Ian Barton  
DAR/CSIRO  
Station Street  
Aspendale, Victoria 3195  
AUSTRALIA  
Voice: 61-35-867666  
GSFCmail: ibarton  
Internet: barton@vax.dar.csiro.au

*SeaWiFS Science Team  
MODIS Science Team*

Saul Alvarez-Borrego  
CICESE  
Rm. 107 Carret. Tij-Ensenada  
Ensenada, MEXICO  
Voice: 52-667-44200  
Voice: 52-667-45050 ext. 4090  
Fax: 52-667-45154  
Internet: rlara@cicese.mx

Sam Bergeson-Willis  
NASA/GSFC/Code 704  
Greenbelt, MD 20771  
Voice: 301-286-5344  
Fax: 301-286-2365  
GSFCmail: sbergesonwillis

Robert Arnone  
NRL/Code 7240  
Stennis Space Center, MS 39527  
Voice: 601-688-5268  
Fax: 601-688-4149  
Omnet: r.arnone  
Internet: arnone@cs1ps2.nrl.navy.mil

Robert Bidigare  
UH/Dept. of Oceanography  
1000 Pope Road  
Honolulu, HI 96822  
Voice: 808-956-6567  
Fax: 808-956-9516  
Omnet: r.bidigare

*SeaWiFS Science Team*

Kevin Arrigo  
NASA/GSFC/Code 971  
Greenbelt, MD 20771  
Voice: 301-286-9634  
Fax: 301-286-2717  
Internet: kevin@shark.gsfc.nasa.gov

*SeaWiFS Science Team*

James Bishop  
LDGO/Columbia University  
Palisades, NY 10964  
Voice: 914-359-2900 ext. 561  
Fax: 914-365-3183  
Omnet: j.bishop.ldgo  
Internet: bishop@lamont.ldgo.columbia.edu

*SeaWiFS Science Team*

Karen Baker  
UCSD/SIO  
LaJolla, CA 92093-0218  
Voice: 619-534-2350  
Fax: 619-534-2997  
Internet: karen@crseo.ucsb.edu

Michael Bristow  
U.S. EPA  
P.O. Box 93478  
Las Vegas, NV 89193  
Voice: 702-798-2272  
Fax: 702-798-2692

William Balch  
MBF/RSMAS/U. of Miami  
4600 Rickenbacker Cswy  
Miami, FL 33149-1098  
Voice: 305-361-4653  
Fax: 305-361-4600  
Omnet: b.balch

*SeaWiFS Science Team*

Otis Brown  
MPO/RSMAS/U. of Miami  
4600 Rickenbacker Causeway  
Miami, FL 33149  
Voice: 305-361-4018  
Fax: 305-361-4622  
Omnet: o.brown  
Internet: otis@rsmas.miami.edu

*SeaWiFS Science Team  
MODIS Science Team*

Robert A. Barnes  
Chemal, Inc.  
P.O. Box 44  
Wallops Island, VA 23337  
Voice: 804-824-1157  
Fax: 301-286-3221  
Omnet: r.barnes

*SeaWiFS Project*

Tony Busalacchi  
NASA/GSFC/Code 970  
Greenbelt, MD 20771  
Voice: 301-286-6171  
Fax: 301-286-2717  
Omnet: t.busalacchi

William Barnes  
NASA/GSFC/Code 970  
Greenbelt, MD 20771  
Voice: 301-286-8670  
Fax: 301-286-2717  
Oment: w.barnes

*SeaWiFS Project*

Dixon Butler  
NASA HQ/Code SED  
300 E Street, SW  
Washington, DC 20546  
Voice: 202-358-0256  
Fax: 202-358-3098  
Omnet: d.butler

Janet Campbell  
Bigelow Laboratory  
McKown Point, P.O. Box 475  
W. Boothbay Harbor, ME 04575  
Voice: 207-633-2173  
Fax: 207-633-6584  
Omnet: j.campbell.janet

Kendall Carder  
Dept. of Marine Science  
Univ. of South Florida  
140 Seventh Avenue, South  
St. Petersburg, FL 33701-5016  
Voice: 813-893-9148  
Fax: 813-893-9189  
Omnet: k.carder

Giancarlo Carrada  
c/o CO.R.I.S.T.A.  
Piazza le Tecchio  
80125 Napoli  
ITALY  
Voice: 39-81-593-5101  
Fax: 39-81-593-3576  
Internet: sznocea@inacriai.criai.it

Judy Chen  
NASA/GSC/Code 970.2  
Greenbelt, MD 20771  
Voice: 301-286-9494  
Fax: 301-286-1213  
Internet: fuh@upolu.gsfc.nasa.gov

Lynne Claffin  
JOI/Suite 800  
1755 Massachusetts Ave, NW  
Washington, DC 20036  
Voice: 202-232-3900  
Fax: 202-232-8203  
Omnet: l.claffin

Dennis K. Clark  
NOAA/NESDIS  
E/RA 28, WWB, Rm. 104  
Washington, DC 20233  
Voice: 301-763-8102  
Fax: 301-763-8020  
Omnet: d.clark.noaa

Mary Cleave  
NASA/GSFC/Code 970.2  
Greenbelt, MD 20771  
Voice: 301-286-1404  
Fax: 301-286-3221  
Omnet: m.cleave

Jim Closs  
NASA/STX/Code 902.2  
Greenbelt, MD 20771  
Voice: 301-286-5033  
Fax: 301-286-3221  
Internet: closs@nssdca.gsfc.nasa.gov

*SeaWiFS Science Team*  
*MODIS Science Team*  
*HIRIS Science Team*

*SeaWiFS Science Team*

*SeaWiFS Science Team*  
*MODIS Science Team*

*SeaWiFS Project*

Patrick Coronado  
NASA/GSFC/Code 930.8  
Greenbelt, MD 20771  
Voice: 301-286-9323  
Fax: 301-286-1635  
Omnet: p.coronado

Glenn Cota  
Graduate Program in Ecology  
University of Tennessee  
Knoxville, TN 37996-1610  
Voice: 615-974-3065  
Fax: 615-974-3067  
Omnet: g.cota  
Internet: cota@utkvtx.utk.edu

Michael Darzi  
General Sciences Corporation  
6100 Chevy Chase Drive  
Laurel, MD 20707-2929  
Voice: 301-286-9150  
Fax: 301-286-2717  
Internet: darzi@ocean1.gsfc.nasa.gov

Curtiss Davis  
JPL/Mail Stop 300-323  
4800 Oak Grove Drive  
Pasadena, CA 91001  
Voice: 818-354-5395  
Fax: 818-393-6146  
Omnet: c.davis.jpl

Eugénie Del-Colle  
NASA/GSFC/Code 902.2  
Greenbelt, MD 20771  
Voice: 301-286-4900  
Fax: 301-286-3221  
Internet: eugenie@upolu.gsfc.nasa.gov

Pierre-Yves Deschamps  
Lab. D'Optique Atmospherique  
Universite des Sciences Lille  
Villeneuve D'Ascq Cedex  
Cedex, 59655 FRANCE  
Voice: 33-204-36697  
Fax: 33-204-34342  
Internet: pyd@loa.citilille.fr

Roland Doerffer  
GKSS Forschungszentrum Geesthacht  
Max-Planck-Strasse  
D-2054 Geesthacht  
GERMANY  
Voice: 49-4152-87-2480  
Fax: 49-4152-87-2444  
Telex: 0218712  
Omnet: w.rosenthal  
Internet: doerffer@dvmc10.gkss.de  
Internet: doerffer@pfsun1.gkss.de

Percy L. Donaghay  
URI/GSO  
Narragansett, RI 02882  
Voice: 401-792-6944  
Fax: 401-792-6160  
Omnet: p.donaghay

*SeaWiFS Project*

*SeaWiFS Science Team*

*SeaWiFS Project*

*HIRIS Science Team*

*SeaWiFS Science Team*

# Proceedings of the First SeaWiFS Science Team Meeting

Antonio L. Elias  
Orbital Sciences Corporation  
14119 Sullyfield Circle  
Chantilly, VA 22021  
Voice: 703-802-8173  
Fax: 703-802-8250

Daniel Endres *SeaWiFS Project*  
NASA/GSFC/Code 970.2  
Greenbelt, MD 20771  
Voice: 301-286-3434  
Fax: 301-286-3221  
GSFCmail: dendres

Wayne Esaias *SeaWiFS Science Team*  
NASA/GSFC/Code 970.2 *MODIS Science Team*  
Greenbelt, MD 20771 *SeaWiFS Project*  
Voice: 301-286-9503  
Fax: 301-286-3221  
Omnet: w.esaias  
Internet: esaias@petrel.gsfc.nasa.gov

Robert Evans *SeaWiFS Science Team*  
MPO/RSMAS/U. of Miami *MODIS Science Team*  
4600 Rickenbacker Causeway  
Miami, FL 33149  
Voice: 305-361-4799  
Fax: 305-361-4622  
Omnet: r.evans

Paul Falkowski *SeaWiFS Science Team*  
OAS Division, Bldg. 318  
Brookhaven National Laboratory  
Upton, NY 11973  
Voice: 516-282-2961  
Fax: 516-282-3246  
Omnet: p.falkowski

Gene Feldman *SeaWiFS Project*  
NASA/GSFC/Code 902.3  
Greenbelt, MD 20771  
Voice: 301-286-9428  
Omnet: g.feldman  
Internet: gene@manono.gsfc.nasa.gov

Jim Firestone *SeaWiFS Project*  
NASA/GSC/Code 970.2  
Greenbelt, MD 20771  
Voice: 301-286-7108  
Fax: 301-286-3221  
Internet: jimf@ocean1.gsfc.nasa.gov

Robert Fraser  
NASA/GSFC/Code 913  
Greenbelt, MD 20771  
Voice: 301-286-9008  
Fax: 301-286-4804  
Internet: fraser@climate.gsfc.nasa.gov

Robert Frouin *SeaWiFS Science Team*  
SIO/Mail Code 0221  
La Jolla, CA 92093-0221  
Voice: 619-534-6243  
Fax: 619-536-7452  
Omnet: r.frouin  
Internet: rfrouin@ucsd.edu

Hajime Fukushima *SeaWiFS Science Team*  
Tokai University  
317 Nishino  
Numazu, 410-03  
JAPAN  
Voice: 81-559-68-1211 ext. 4425  
Fax: 81-559-68-1155  
Omnet: h.fukushima  
Internet: hajime@numazugw.cc.u-tokai.ac.jp

Carlos Garcia *SeaWiFS Science Team*  
Departamento de Fisica  
Fundacao Universidade do Rio Grande  
Rua Alfredo Huch, 475  
Rio Grande, 96201-900  
BRAZIL  
Voice: 55-532-323200 ext. 181  
Fax: 55-532-329094  
Bitnet: dfsgar@brfurg.bitnet

David Glover *SeaWiFS Science Team*  
WHOI/Clark 4  
Woods Hole, MA 02543  
Voice: 508-457-2000 ext. 2656  
Fax: 508-457-2193  
Omnet: d.glover  
Internet: david@plaid.whoi.edu

Howard Gordon *SeaWiFS Science Team*  
UM/Dept. of Physics *MODIS Science Team*  
Coral Gables, FL 33124  
Voice: 305-284-2323  
Fax: 305-284-4222  
Omnet: h.gordon  
Internet: gordon@phyvax.ir.miami.edu

Watson Gregg *SeaWiFS Project*  
NASA/GSFC/Code 902.3  
Greenbelt, MD 20771  
Voice: 301-286-3464  
Omnet: w.gregg

Connie Hall *SeaWiFS Project*  
NASA/GSC/Code 970.2  
Greenbelt, MD 20878  
Voice: 301-286-4072  
Fax: 301-286-3221  
Internet: connie@manono.gsfc.nasa.gov

David Halpern *SeaWiFS Science Team*  
JPL/Mail Stop 300-323  
4800 Oak Grove Drive  
Pasadena, CA 91109  
Voice: 818-354-5327  
Fax: 818-393-6720  
Omnet: d.halpern

Lynn Halpern  
HSTX  
7604 Ora Glen Dr., Suite 300  
Greenbelt, MD 20770  
Voice: 301-513-1690  
Fax: 301-513-1608  
Internet: halpern@eosdev1.gsfc.nasa.gov



Lawrence Harding  
UM/0112 Skinner Hall  
College Park, MD 20742  
Voice: 301-405-6372  
Fax: 301-314-9581  
Internet: hardingl@mbimail.umd.edu

Eileen Hofmann *SeaWiFS Science Team*  
ODU/CCPO/Crittenton Hall  
Norfolk, VA 23529  
Voice: 804-683-5334  
Fax: 804-683-5550  
Omnet: e.hofmann  
Internet: hofmann@kuroshio.ccpo.odu.edu

Frank Hoge *SeaWiFS Science Team*  
NASA/GSFC/WFF *MODIS Science Team*  
Wallops Island, VA 23337  
Voice: 804-824-1567  
Fax: 804-824-2343  
Fax: 804-824-1036  
Omnet: f.hoge

Alan Holmes  
Hughes/SBRC  
75 Coromar Drive  
Goleta, CA 93117  
Voice: 805-562-4013  
Fax: 805-562-4024

Stanford Hooker *SeaWiFS Project*  
NASA/GSFC/Code 970.2  
Greenbelt, MD 20771  
Voice: 301-286-9503  
Fax: 301-286-3221  
Omnet: s.hooker  
Internet: stan@ardbeg.gsfc.nasa.gov

Douglas Ilg  
4400 Forbes Blvd.  
Lanham, MD 20706  
Voice: 301-794-5362  
Fax: 301-513-1608  
Internet: dilg@spso.gsfc.nasa.gov

Richard Iverson *SeaWiFS Science Team*  
Department of Oceanography  
Florida State University  
Tallahassee, FL 32306-3048  
Voice: 904-644-1730  
Fax: 904-644-2581  
Omnet: r.iveron

Carol Johnson  
NIST/Bldg, 221, Room A221  
Gaithersburg, MD 20899  
Voice: 301-975-2322  
Fax: 301-840-8551  
Internet: cjohnson@enh.nist.gov

Mike Jones  
NASA/GSC/Code 902.3  
Greenbelt, MD 20771  
Voice: 301-286-8025  
Fax: 301-286-3221  
Internet: mike@upolu.gsfc.nasa.gov

Mati Kahru  
Stockholm University  
Dept. of Physical Geography  
Stockholm, S10691  
SWEDEN  
Voice: 46-8-164958  
Fax: 46-8-164818  
Omnet: o.rud  
Internet: mati@natgeo.su.se

Daniel Kamykowski *SeaWiFS Science Team*  
NCSU/MEAS/Box 8208  
Raleigh, NC 27695  
Voice: 919-515-7894  
Fax: 919-515-7802  
Omnet: d.kamykowsi

Richard Kiang  
NASA/GSFC/Code 902.3  
Greenbelt, MD 20771  
Voice: 301-286-2507  
Internet: kiang@faveinte.gsfc.nasa.gov

Dale Kiefer *SeaWiFS Science Team*  
USC/Dept. of Biology  
P.O. Box 0371  
Los Angeles, CA 90089-0371  
Voice: 213-740-5814  
Fax: 213-740-8123  
Omnet: d.kiefer

Michael King  
NASA/GSFC/Code 900  
Greenbelt, MD 20771  
Voice: 301-286-8228  
Fax: 301-286-4884  
Internet: king@climate.gsfc.nasa.gov

Robert Kirk *SeaWiFS Project*  
NASA/GSFC/Code 970.2  
Greenbelt, MD 20771  
Voice: 301-286-7895  
Fax: 301-286-3221  
Omnet: r.kirk

Motoaki Kishino *SeaWiFS Science Team*  
Inst. of Phys. & Chem. Res.  
Hirosawa 2-1  
Wako-shi, Saitama, 351-01  
JAPAN  
Voice: 81-48-462-1111 ext. 3635  
Fax: 81-48-462-1449  
Internet: kishino@rkna50.riken.go.jp  
Span: rik835::in%"kishino@rkna50.riken.go.jp"

Chester Koblinsky  
NASA/GSFC/Code 971  
Greenbelt, MD 20771  
Voice: 301-286-4718  
Fax: 301-286-2717  
Omnet: c.koblinsky

Oleg Kopelevich *SeaWiFS Science Team*  
P.P. Shirshov Inst. of Oceanology  
23 Krasikova St.

# Proceedings of the First SeaWiFS Science Team Meeting

Moscow, 117218  
RUSSIA  
Voice: 7-095-124-7583  
Fax: 7-095-292-6511  
Telex: 411968 Okean SU  
Omnet: p.shirshov

Gennady Korotaev *SeaWiFS Science Team*  
Marine Hydrophysical Institute  
4 Kapitanskaya St.  
Sevastopol, 335000  
UKRAINE  
Voice: 06-90-52-0779  
Voice: 06-90-5-20452  
Fax: 06-90-41-1325  
Telex: 187115 SWSO SU  
Omnet: mhi.sevastopol  
Internet: mhi.sevastopol.ua@ussr.eu.net

Norman Kuring *SeaWiFS Project*  
NASA/GSFC/Code 902.3  
Greenbelt, MD 20771  
Voice: 301-286-2264  
Fax: 301-286-3221  
Internet: norman@manono.gsfc.nasa.gov

Ruben Lara-Lara *SeaWiFS Science Team*  
CICESE  
Km. 107 Carret Tij-Ensenada  
Ensenada, BC MEXICO  
Voice: 52-667-4-42-00  
Fax: 52-667-4-51-54  
Internet: rlara@cicese.mx

R. Michael Laurs  
NOAA/NMFS  
P.O. Box 271  
La Jolla, CA 92038  
Voice: 619-546-7086  
Fax: 619-546-5614  
Omnet: m.laurs

Marlon Lewis *SeaWiFS Science Team*  
Department of Oceanography  
Dalhousie University  
Halifax, Nova Scotia B3H 4J1  
Voice: 902-492-4780  
Fax: 902-492-4781  
Omnet: m.lewis  
Internet: marlon@predator.ocean.dal.ca

Patricia Liggett  
NASA HQ/Code SED  
Washington, DC 20546  
Voice: 202-358-0755  
Fax: 202-358-3098  
Omnet: p.liggett

Michael Lizotte  
BDM International, Inc., Suite 340  
409 Third Street, SW  
Washington, DC 20024  
Voice: 202-863-9952  
Fax: 202-863-8407  
Omnet: m.lizotte

Mark Luther *SeaWiFS Science Team*  
Department of Marine Science  
University of South Florida  
140 Seventh Avenue, South  
St. Petersburg, FL 33701  
Voice: 813-893-9528  
Fax: 813-893-9189  
Omnet: m.luther  
Internet: luther@marine.usf.edu

Keith Lyon  
Orbital Sciences Corporation  
P.O. Box 10840  
Chantilly, VA 22021  
Voice: 703-802-8009  
Fax: 703-802-8255  
Omnet: k.lyon

Satsuki Matsumura *SeaWiFS Science Team*  
Natl. Res. Inst. of Far Seas Fish.  
5-7-1 Orido  
Shimizu, Shizuoka, 424  
JAPAN  
Voice: 81-543-34-0715  
Fax: 81-543-35-9642  
Telex: 03965689 FARSEA J  
Omnet: s.matsumura

Charles McClain *SeaWiFS Science Team*  
*SeaWiFS Project*  
NASA/GSFC/Code 971  
Greenbelt, MD 20771  
Voice: 301-286-5377  
Fax: 301-286-2717  
Omnet: c.mcclain  
Internet: mcclain@ocean1.gsfc.nasa.gov

Scott McLean  
Satlantic Inc.  
Richmond Terminal Pier 9  
3295 Barrington Street  
Halifax, B3K5X8  
Nova Scotia  
Voice: 902-492-4780  
Fax: 902-492-4781  
Internet: scott@predator.ocean.dal.ca

Blanche Meeson  
NASA/GSFC/Code 902.2  
Greenbelt, MD 20771  
Voice: 301-286-9282  
Fax: 301-286-3221  
Internet: meeson@nssdca.gsfc.nasa.gov

Greg Mitchell *SeaWiFS Science Team*  
UCSD/MRD 0218  
LaJolla, CA 92093-0218  
Voice: 619-534-2687  
Fax: 619-534-2997  
Omnet: g.mitchell  
Internet: bgmitchell@ucsd.edu

Donald Montgomery  
U.S. Naval Observatory  
Washington, DC  
Voice: 202-653-1610  
Fax: 202-653-1435  
Omnet: d.montgomery

André Morel  
Lab de Physique a Chimie Marines  
Université Pierre et Marie Curie  
BP 08, 06230 Villefranche Sur Mer  
FRANCE  
Voice: 33-93-76-37-11  
Fax: 33-93-76-37-39  
Omnet: a.morel

James Mueller  
SDSU/CHORS  
6505 Alvarado Road, Suite 206  
San Diego, CA 92120-5005  
Voice: 619-594-2230  
Fax: 619-594-4570  
Omnet: j.mueller

Frank Muller-Karger  
NASA HQ/Code SEP  
Washington, DC 20546  
Voice: 202-358-0238  
Fax: 202-358-3098  
Omnet: f.muller.karger  
Internet: carib@carbon.marine.usf.edu

Christiane Nill  
ESRIN/ESA  
Via Galileo Galilei  
C.P. 64 Frascati, 00044  
ITALY  
Voice: 39-6-94180-675  
Fax: 39-6-94180-361  
Internet: jana@mail.esrin.esa.it

Lola Olsen  
NASA/GSFC/Code 902.2  
Greenbelt, MD 20771  
Voice: 301-286-9760  
Fax: 301-286-3221  
Internet: olsen@eosdata.gsfc.nasa.gov

John Parslow  
CSIRO/Div. of Fisheries  
GPO Box 1538  
Hobart Tasmania 7001  
AUSTRALIA  
Voice: 61-02-206202  
Omnet: j.parslow  
Internet: parslow@aqueous.ml.csiro.au

Frederick Patt  
NASA/GSC/Code 970.2  
Greenbelt, MD 20771  
Voice: 301-286-4569  
Internet: patt@amarna.gsfc.nasa.gov

Philip Pease  
NASA/GSFC/Code 902.2  
Greenbelt, MD 20771  
Voice: 301-422-1285  
Fax: 301-286-3221  
Internet: pease@eosdata.gsfc.nasa.gov

Bill Peterson  
NOAA/NMFS  
1335 East-West Highway  
Silver Spring, MD 20910  
Voice: 301-713-2239  
Fax: 301-713-2258  
Omnet: w.peterson

Lasse H. Pettersson  
Nansen Environ. and Remote Sensing Cntr  
Edv. Griegsvei 3A  
Bergen, NORWAY, N-5037  
Voice: 47-5-2972-88  
Fax: 47-5-2000-50  
Omnet: o.johannessen  
Internet: lasse@nanvax.nrsc.no

Michael Reeve  
NSF/Room 609  
1800 9th Street, NW  
Washington, DC 20550  
Voice: 202-357-4600  
Fax: 202-357-7621  
Omnet: m.reeve

Lisa Rexrode  
NASA/GSC/Code 970.2  
Greenbelt, MD 20771  
Voice: 301-286-6614  
Fax: 301-286-3221  
Internet: lisa@petrel.gsfc.nasa.gov

Maurizio Ribera  
Stazione Zoologica "A. Dohrn"  
Villa Comunale  
Napoli, ITALY  
Voice: 39-81-583-3245  
Fax: 39-81-764-1355  
Internet: sznocea@inacriai.criai.it

Richard Roberts  
Hughes/SBRC  
75 Coromar Drive  
Goleta, CA 93117  
Voice: 805-562-7168  
Fax: 805-562-4024  
Omnet: r.roberts.sbrc

Egil Sakshaug  
Trondhjem Biological Station  
University of Trondheim  
Bynesveien 46  
N-7018 Trondheim  
NORWAY  
Voice: 47-7-591583  
Fax: 47-7-591597  
Omnet: o.johannessen

Vincent Salomonson  
NASA/GSFC/Code 900  
Greenbelt, MD 20771  
Voice: 301-286-8601  
Omnet: v.salomonson

*SeaWiFS Project*

*SeaWiFS Science Team*

Proceedings of the First SeaWiFS Science Team Meeting

A. Cemal Saydam  
Metu Grad. School of Marine Science  
Erdemli, TURKEY  
Voice: 90-7586-2406  
Voice: 90-7586-2150  
Fax: 90-7586-2327  
Omnet: u.unluata

Donald Scavia  
NOAA/Room 518  
1825 Connecticut Ave., NW  
Washington, DC 20235  
Voice: 202-606-4330  
Fax: 202-606-4334  
Omnet: d.scavia

Martha Scott  
NSF/Room 609  
1800 G Street, NW  
Washington, DC 20009  
Voice: 202-357-7910  
Fax: 202-357-7621  
Omnet: m.scott

Frank Shillington *SeaWiFS Science Team*  
Department of Oceanography  
University of Cape Town  
Rondebosch 7700  
SOUTH AFRICA  
Voice: 27-21-650-3278  
Fax: 27-21-650-3979  
Omnet: capetown.ocean  
Internet: shill@physci.uct.ac.za

David Siegel *SeaWiFS Science Team*  
UCSB/CRSEO  
Santa Barbara, CA 93106-3060  
Voice: 805-893-4547  
Fax: 805-893-2578  
Omnet: d.siegel  
Internet: daves@crseo.ucsb.edu

Mike Sissenwine  
NOAA/NMFS  
1335 East-West Highway  
Silver Spring, MD 20910  
Voice: 301-713-2239  
Fax: 301-713-2258  
Omnet: m.sissenwine

Philip Slater *SeaWiFS Science Team*  
University of Arizona  
1600 N. Country Club, Suite 100  
Tucson, AZ 85716  
Voice: 602-621-4242  
Fax: 602-621-8292  
GSFCmail: pslater

Raymond Smith *SeaWiFS Science Team*  
CRSEO/UCSB  
Santa Barbara, CA 93106  
Voice: 805-893-4709  
Fax: 805-893-2578  
Omnet: r.smith.ucsb  
Internet: ray@crseo.ucsb.edu

Petra Stegmann  
URI/GSO  
S. Ferry Road  
Narragansett, RI 02882  
Voice: 401-792-6863  
Fax: 401-792-6728  
Omnet: p.stegmann  
Internet: petra@uri.gso.uri.edu

Boris Sturm *SeaWiFS Science Team*  
Joint Research Center of the CEC  
I-21020 Ispra (Va)  
ITALY  
Voice: 39-332-789934  
Fax: 39-332-789034  
Omnet: m.ooms  
Internet: boris.sturm@jrc.it

Kathy Sullivan  
NOAA  
Herbert Hoover Bldg., Room 5809  
14<sup>th</sup> & Constitution, NW  
Washington, DC 20230  
Voice: 202-482-1437  
Fax: 202-482-5231  
Omnet: k.sullivan

Tomas Svitek  
Orbital Sciences Corporation  
P.O. Box 10840  
Chantilly, VA 22021  
Voice: 703-802-8169  
Fax: 703-802-8255

Neil Tindale *SeaWiFS Science Team*  
TAMU/Dept. of Meteorology  
College Station, TX 77843  
Voice: 409-862-4401  
Omnet: n.tindale  
Internet: tindale@ariel.tamu.edu

Ronald Tipper  
JOI/Suite 800  
1755 Massachusetts Ave., NW  
Washington, DC 20036  
Voice: 202-232-3900  
Fax: 202-232-8203  
Omnet: r.tipper

Charles Trees *SeaWiFS Science Team*  
SDSU/CHORS  
6505 Alvarado Road, Suite 206  
San Diego, CA 92120-5005  
Voice: 619-594-2241  
Fax: 619-594-4570  
Omnet: c.trees

Ümit Ünlüata *SeaWiFS Science Team*  
Institute of Marine Sciences  
Middle East Technical University  
P.O. Box 28  
Erdemli, İçel 33731  
TURKEY  
Voice: 90-7-586-1150  
Omnet: u.unluata

Charles Vermillion  
NASA/GSFC/Code 930.2  
Greenbelt, MD 20771  
Voice: 301-286-5111  
Fax: 301-286-1635  
GSFCmail: cvermillion  
Omnet: c.vermillion

*SeaWiFS Project*

Warren Wiscombe  
NASA/GSFC/Code 913  
Greenbelt, MD 20771  
Voice: 301-286-8499  
Internet: wiscombe@climate.gsfc.nasa.gov

John Walsh  
Department of Marine Science  
University of South Florida  
140 Seventh Avenue, South  
St. Petersburg, FL 33701  
Voice: 813-893-9164  
Fax: 813-893-9189  
Omnet: j.walsh.usf

*SeaWiFS Science Team*

Bob Woodward  
General Sciences Corporation  
6100 Chevy Chase Drive  
Laurel, MD 20707-2929  
Voice: 301-286-1403  
Fax: 301-286-3221  
Internet: woodward@ocean1.gsfc.nasa.gov

Leif Wastenson  
Stockholm University  
Remote Sensing Laboratory  
Dept. of Physical Geography  
S-106 91 Stockholm  
SWEDEN  
Voice: 46-8-164790  
Fax: 46-8-164818

*SeaWiFS Science Team*

Shiming Xu  
NCSA  
605 E. Springfield Ave.  
Champaign, IL 61820  
Voice: 217-244-3830  
Fax: 217-244-1987  
Internet: sxu@ncsa.uiuc.edu

Marcel Wernand  
Netherlands Inst. for Sea Res.  
P.O. Box 59  
1790 AB Den Burg  
Texel  
THE NETHERLANDS  
Voice: 2220-69417  
Fax: 2220-19674  
Omnet: nioz.texel  
Internet: wernand@nioz.nl

*SeaWiFS Science Team*

Charles Yentsch  
Bigelow Laboratory  
McKown Point  
W. Boothbay Harbor, ME 04575  
Voice: 207-633-2173  
Fax: 207-633-6584  
Omnet: c.yentsch.charles

Stephen Wharton  
NASA/GSFC/Code 902  
Greenbelt, MD 20771  
Voice: 301-286-9041  
GSFCmail: swarton

James Yoder  
URI/GSO  
Kingston, RI 02881  
Voice: 401-792-6864  
Fax: 401-792-8098  
Omnet: j.yoder  
Internet: yoder@biosat.gso.uri.edu

Diane E. Wickland  
NASA HQ/Code SEP03  
Washington, D.C. 20546  
Voice: 202-358-0272  
Fax: 202-358-3098  
Omnet: d.wickland

Ron Zaneveld  
Oregon State University  
Ocean. Admin. Bldg. 104  
Corvallis, OR 97331-5503  
Voice: 503-737-3571  
Fax: 503-737-2064  
Omnet: r.zaneveld

Stan Wilson  
NOAA/NOS/Suite 611  
1825 Connecticut Ave., NW  
Washington, DC 20235  
Voice: 202-606-4140  
Fax: 202-606-4050  
Omnet: s.wilson.ocean

Robert Winokur  
Oceanographer of the Navy/N096  
Chief of Naval Operations  
Washington, DC 20392  
Voice: 202-653-1299  
Fax: 202-653-1435  
Omnet: r.winokur

Dorothy J. Zukor  
NASA/GSFC/Code 900  
Greenbelt, MD 20771  
Voice: 301-286-8551  
Fax: 301-286-3884  
GSFCmail: dzukor

## GLOSSARY

This glossary only contains entries from Sections 1-4 and the appendices of this document—acronyms used in Section 5, the Science Team abstracts, are not defined here.

AOL Airborne Oceanographic Lidar  
AOP Apparent Optical Property  
ARI Accelerated Research Initiative  
ASAP As Soon As Possible  
ASCII American Standard Code for Information Interchange  
ASI Italian Space Agency  
AVHRR Advanced Very High Resolution Radiometer

## Proceedings of the First SeaWiFS Science Team Meeting

BATS Bermuda Atlantic Time Series	GUI Graphical User Interface
BBOP Bermuda Bio-Optical Profiler	HDF Hierarchical Data Format
BOMS Bio-Optical Moored Systems	HP Hewlett Packard
BOPS Bio-Optical Profiling System	HOTS Hawaiian Optical Time Series
BRDF Bidirectional Reflectance Distribution Function	HPLC High Performance Liquid Chromatography
BWI Baltimore-Washington International (airport)	HQ Headquarters
CalCoFI California Cooperative Fisheries Institute	HRPT High Resolution Picture Transmission
Case 1 Water whose reflectance is determined solely by absorption.	IAPSO International Association for the Physical Sciences of the Ocean
Case 2 Water whose reflectance is significantly influenced by scattering.	IBM International Business Machines
CCPO Center for Coastal Physical Oceanography (Old Dominion University)	IDL Interface Design Language
CDOM Colored Dissolved Organic Material	IMS Information Management System
CDR Critical Design Review	IOP Inherent Optical Property
CD-ROM Compact Disk-Read Only Memory	ISCCP International Satellite Cloud Climatology Project
CHORS Center for Hydro-Optics and Remote Sensing (San Diego State University)	JAM JYACC Application Manager
CICESE <i>Centro de Investigación Científica y de Educación Superior de Ensenada</i> (Mexico)	JGOFS Joint Global Ocean Flux Study
COOP Coastal Ocean Optics Program	JOI Joint Oceanographic Institute
COTS Commercial Off-The-Shelf (Software)	JPL Jet Propulsion Laboratory
cpu Central Processing Unit	LAC Local Area Coverage, fine resolution satellite data with a nominal ground resolution of approximately 1 km.
CRN Italian Research Council	LDGO Lamon-Doherty Geological Observatory (Columbia University)
CRSEO Center for Remote Sensing and Environmental Optics (University of California at Santa Barbara)	Level-0 Raw data.
CSL Computer Systems Laboratory	Level-1 Calibrated radiances.
CTD Conductivity Temperature Depth	Level-2 Derived products.
CZCS Coastal Zone Color Scanner	Level-3 Gridded and averaged derived products.
DAAC Distributed Active Archive Center	LRER Long-Range Ecological Research
DAT Digital Audio Tape	MASSS Multi-Agency Ship-Scheduling for SeaWiFS
DEC Digital Equipment Corporation	MBARI Monterey Bay Aquarium Research Institute
DOC Dissolved Organic Carbon	MLE Maximum Likelihood Estimator
DOE Department of Energy	MLML Moss Landing Marine Laboratory
DOM Dissolved Organic Matter	MOBY Marine Optical Buoy
DOS Disk Operating System	MOCE Marine Optical Characterization Experiment
DSP Not an acronym, an image display and analysis package developed at RSMAS University of Miami.	MODIS Moderate Resolution Image Spectrometer
EAFB Edwards Air Force Base	NASA National Aeronautics and Space Administration
EEZ Exclusive Economic Zone	NASCOM NASA Communications
EOS Earth Observing Satellite	NCSA National Center for Supercomputing Applications
EOSDIS Earth Observing Satellite Data Information System	NCSU North Carolina State University
EPA Environmental Protection Agency	NESDIS National Environmental Satellite Data Information Service
ESA European Space Agency	NET Nimbus Experiment Team
FLUPAC (Geochemical) Fluxes in the Pacific (Ocean)	NIST National Institute of Standards of Technology
FNOC Fleet Numerical Oceanography Center	NMC National Meteorological Center
FTP File Transfer Protocol	NMFS National Marine Fisheries Service
GAC Global Area Coverage, coarse resolution satellite data with a nominal ground resolution of approximately 4 km.	NOAA National Oceanic and Atmospheric Administration
GISS Goddard Institute for Space Studies	NOS National Ocean Service
GMT Greenwich Mean Time	NRA NASA Research Announcement
GPS Global Positioning System	NRL Naval Research Laboratory
GSFC Goddard Space Flight Center	NSF National Science Foundation
GSO Graduate School of Oceanography (URI)	ODU Old Dominion University
	OFFI Optical Free Fall Instrument
	OLIPAC Oligotrophy in the Pacific (Ocean)
	ONR Office of Naval Research

OS Operating System  
 OSC Orbital Sciences Corporation  
 OSU Oregon State University  
 PAR Photosynthetically Available Radiation  
 PC (IBM) Personal Computer  
 PDR Preliminary Design Review  
 PI Principal Investigator

R&A Research and Applications  
 RF Radio Frequency  
 RISC Reduced Instruction Set Computer  
 RSMAS Rosenstiel School for Marine and Atmospheric Sciences (University of Miami)  
 SBRC Santa Barbara Research Center  
 SDPS SeaWiFS Data Processing System  
 SDSU San Diego State University  
 SEAPAK Not an acronym, an image display and analysis package developed at GSFC.  
 SeaWiFS Sea-viewing Wide Field-of-view Sensor  
 SGI Silicon Graphics, Incorporated  
 SIO Scripps Institution of Oceanography  
 SOW Statement of Work  
 SPO SeaWiFS Project Office  
 SST Sea Surface Temperature or SeaWiFS Science Team (depending on usage)  
 SUN Sun Microsystems

TBD To Be Determined  
 TIROS Television Infrared Observation Satellite  
 TM Technical Memorandum  
 TOMS Total Ozone Mapping Spectrometer  
 TOVS TIROS Operational Vertical Sounder  
 TV Thermal Vacuum

UARS Upper Atmosphere Research Satellite  
 UCMBO University of California Marine Bio-Optics  
 UCSB University of California at Santa Barbara  
 UCSD University of California at San Diego  
 UH University of Hawaii  
 UIM/X User Interface Management/X-Windows  
 UM University of Miami  
 UPS Uninterruptable Power System  
 URI University of Rhode Island  
 USC University of Southern California  
 USF University of South Florida  
 UWG User Working Group

V0 Version 0  
 V1 Version 1  
 VAX Virtual Address Extension

VI Virtual Instrument  
 VMS Virtual Memory System  
 WFF Wallops Flight Facility  
 WHOI Woods Hole Oceanographic Institute  
 WOCE World Ocean Circulation Experiment

## SYMBOLS

$\Delta p\text{CO}_2$  Partial pressure difference of  $\text{CO}_2$  between air and sea water.  
 $\tau_a$  Aerosol optical thickness.  
 $[chl. a]/K$  Concentration of chlorophyll *a* over *K*, the diffuse attenuation coefficient.  
 $E_d(z, \lambda)$  Downwelled spectral irradiance.  
 $E_u(z, \lambda)$  Upwelled spectral irradiance.  
*f*-ratio The ratio of new to total production.  
 $I_0$  Surface downwelling irradiance.  
 $K(z, \lambda)$  Diffuse attenuation coefficient.  
 $K_0(\lambda)$  Diffuse attenuation coefficient at  $z = 0$ .  
 $L_a$  Aerosol radiance.  
 $L_u(z, \lambda)$  Upwelled spectral radiance.  
 $L_{WN}(\lambda)$  Normalized water-leaving radiance.  
*N* The total number of something.  
 $Q$   $L_u(0^-, \lambda)$  to  $E_u(0^-, \lambda)$  relation factor (theoretically equal to  $\pi$ ).  
*x* Abscissa or longitudinal coordinate.  
*y* Ordinate or meridional coordinate.

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